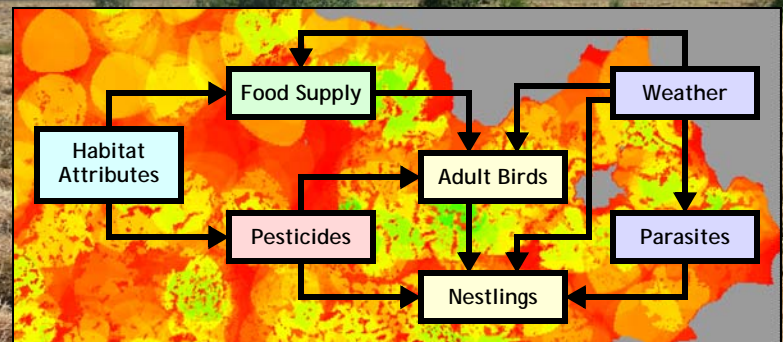


Space, Pattern, and the HexSim Model



Nathan H. Schumaker



HexSim History

**Has existed in some form
for about 15 years now...**

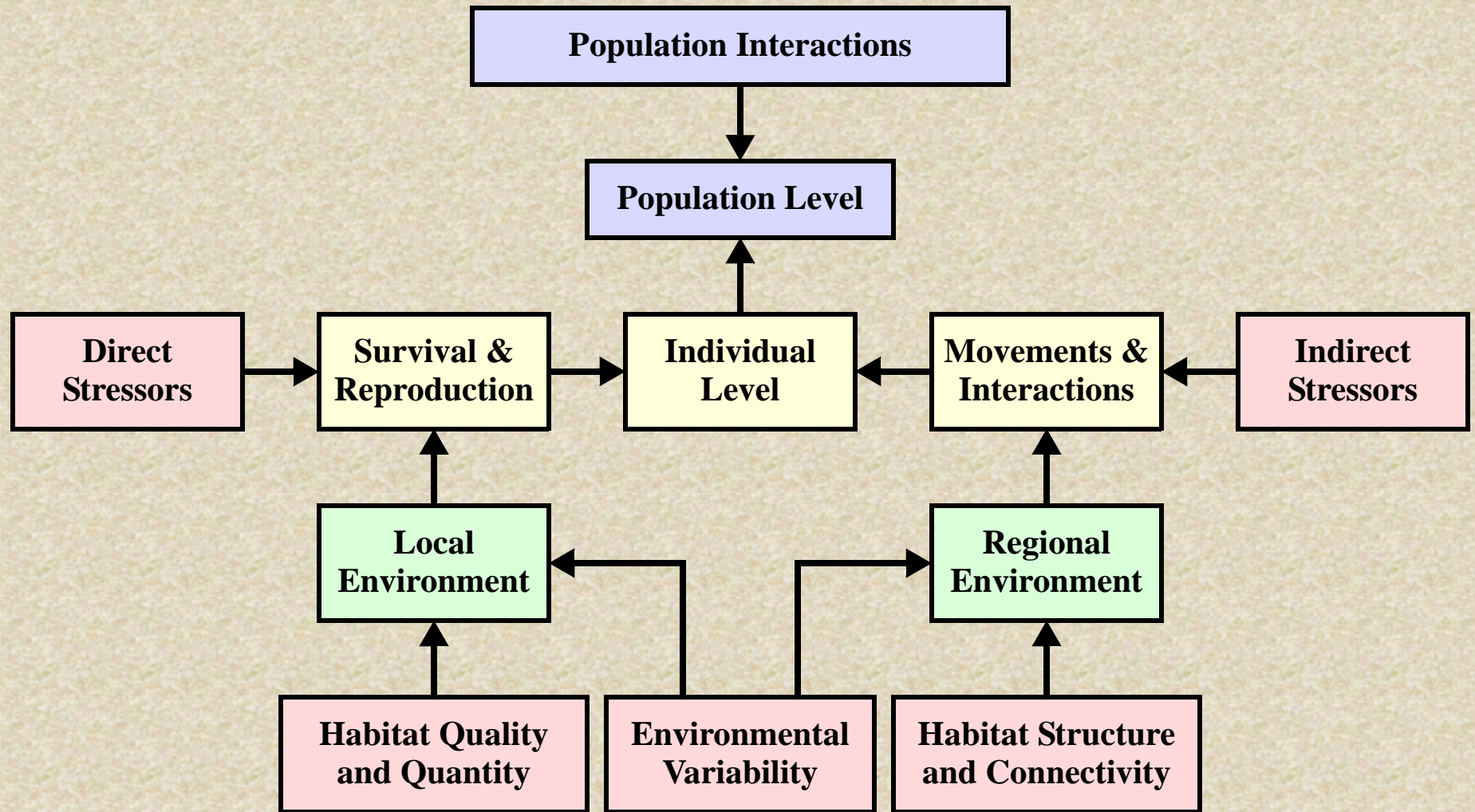
- Circa 1992**
Original version began as a grad student project
- 1995 - 2000**
Focused mostly on landscape structure
- 2001 - Present**
Expanded to address multiple species / stressors

What Is It?

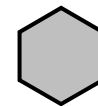
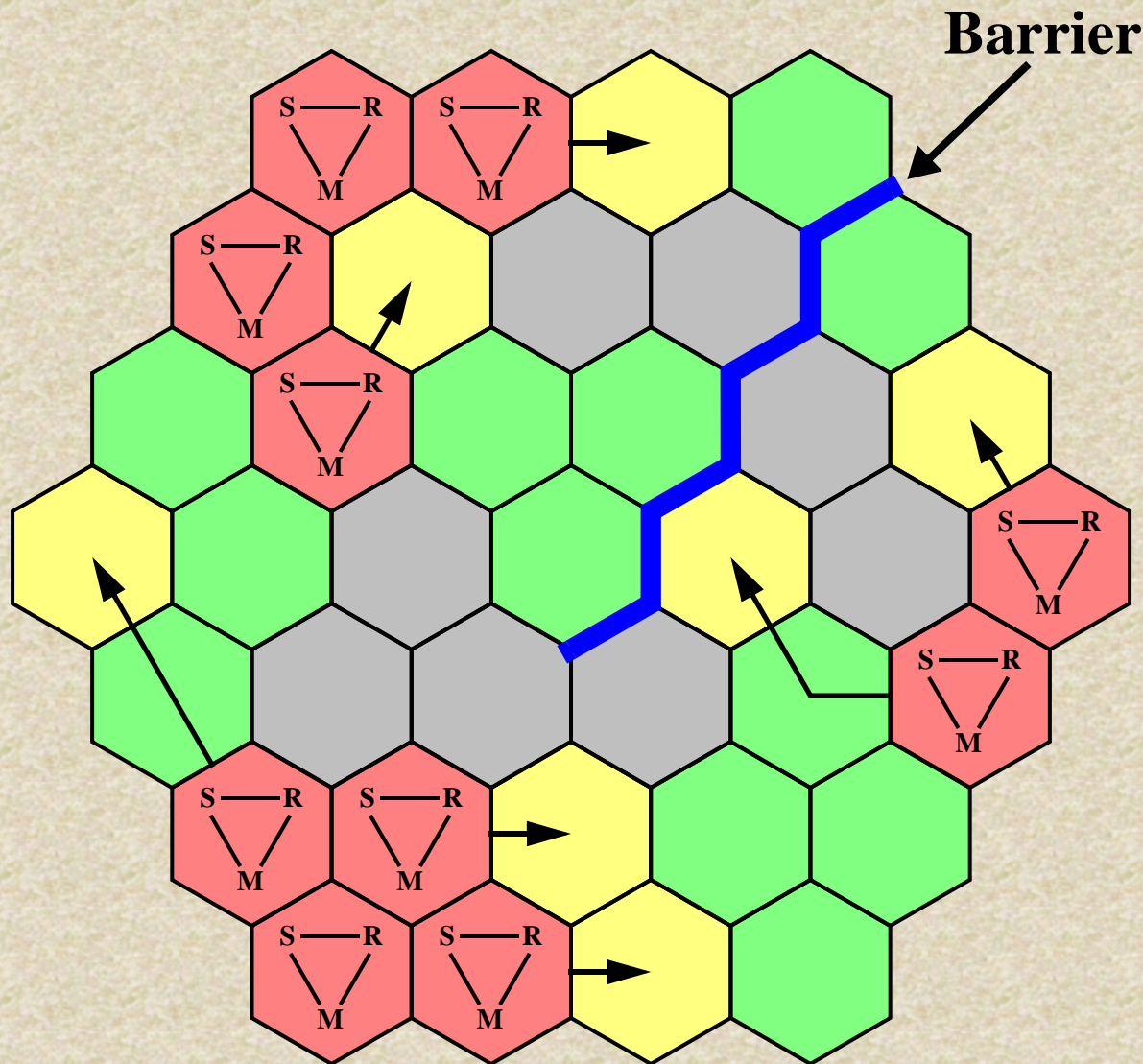
A SEPM that attempts to balance realism, generality, and parsimony

- ▣ Life cycle composed of user-defined events**
- ▣ Most events have spatial drivers**
- ▣ Works with individuals, and with groups**
- ▣ Simulations can be simple, with little data**
- ▣ But, complexity can be easily increased**

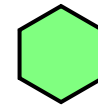
Conceptual Schematic



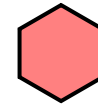
HexSim Basics



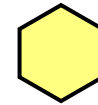
Non-Habitat



Available Habitat



Occupied Habitat



Colonized Habitat



Movement Path

S = Survival

R = Reproduction

M = Movement

Time Steps + Replicates

Life Cycle for Population p

Event 1
Event 2

Event n

Event Palate

Matrix Multiplication

- Survival Only
- Fecundity Only
- Full Projection

Movement
Interactions
Census

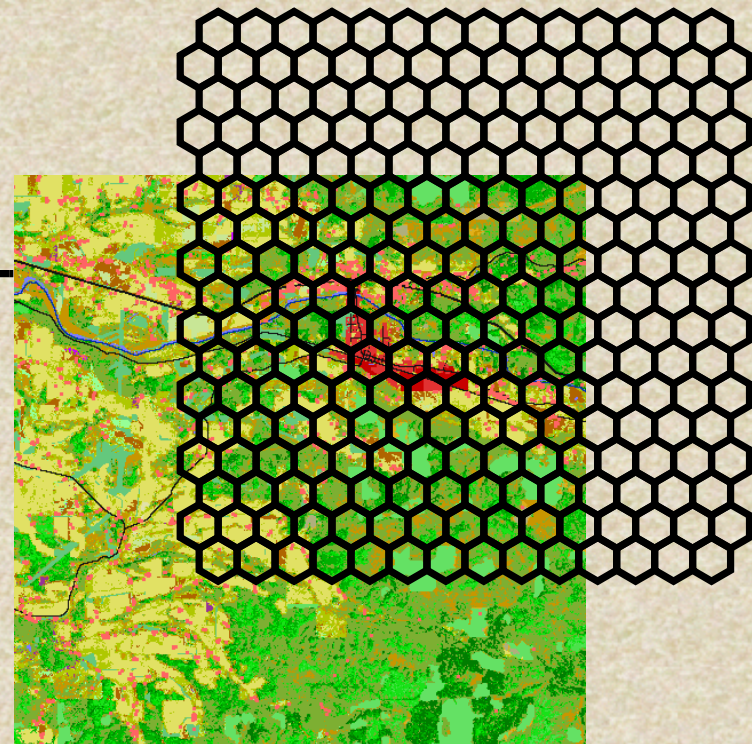
Event Parameterization

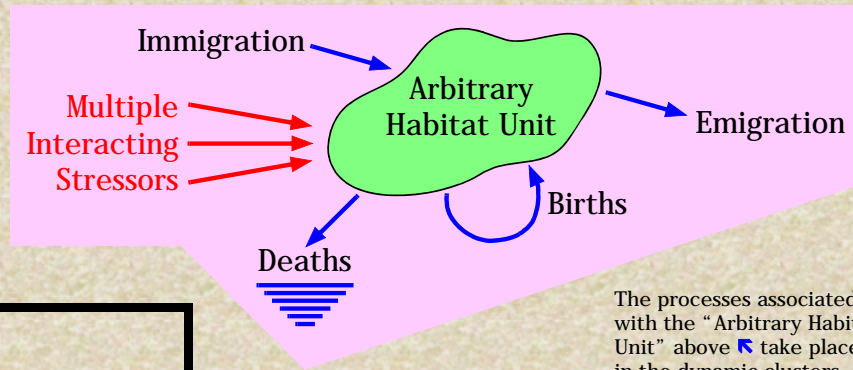
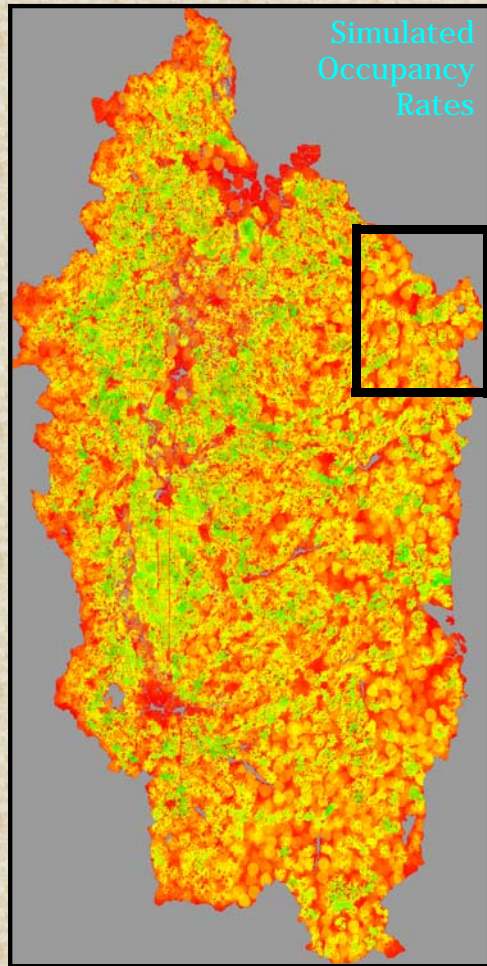
Spatial Data Layers

- Habitat Data
- Stressor Data
- Movement Barriers
- Other Spatial Data

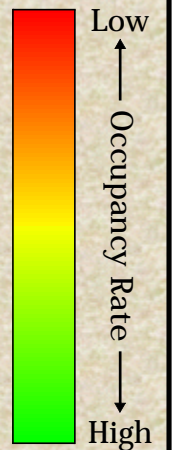
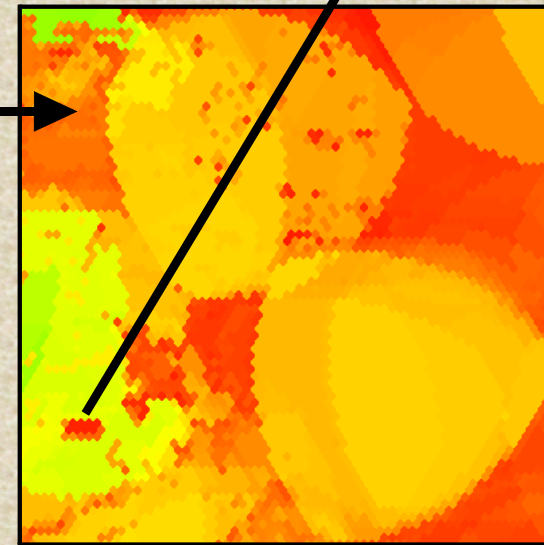
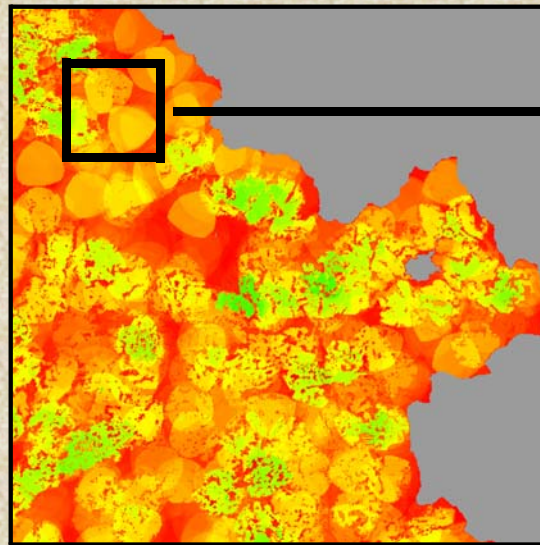
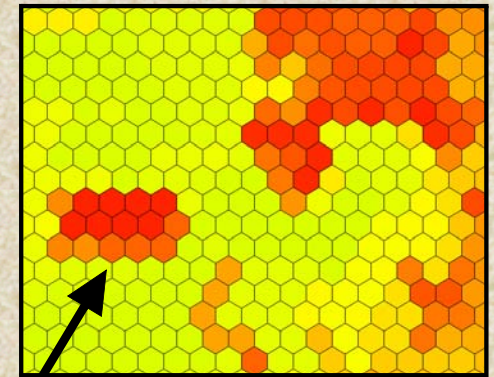
Event Parameters

Data Logging

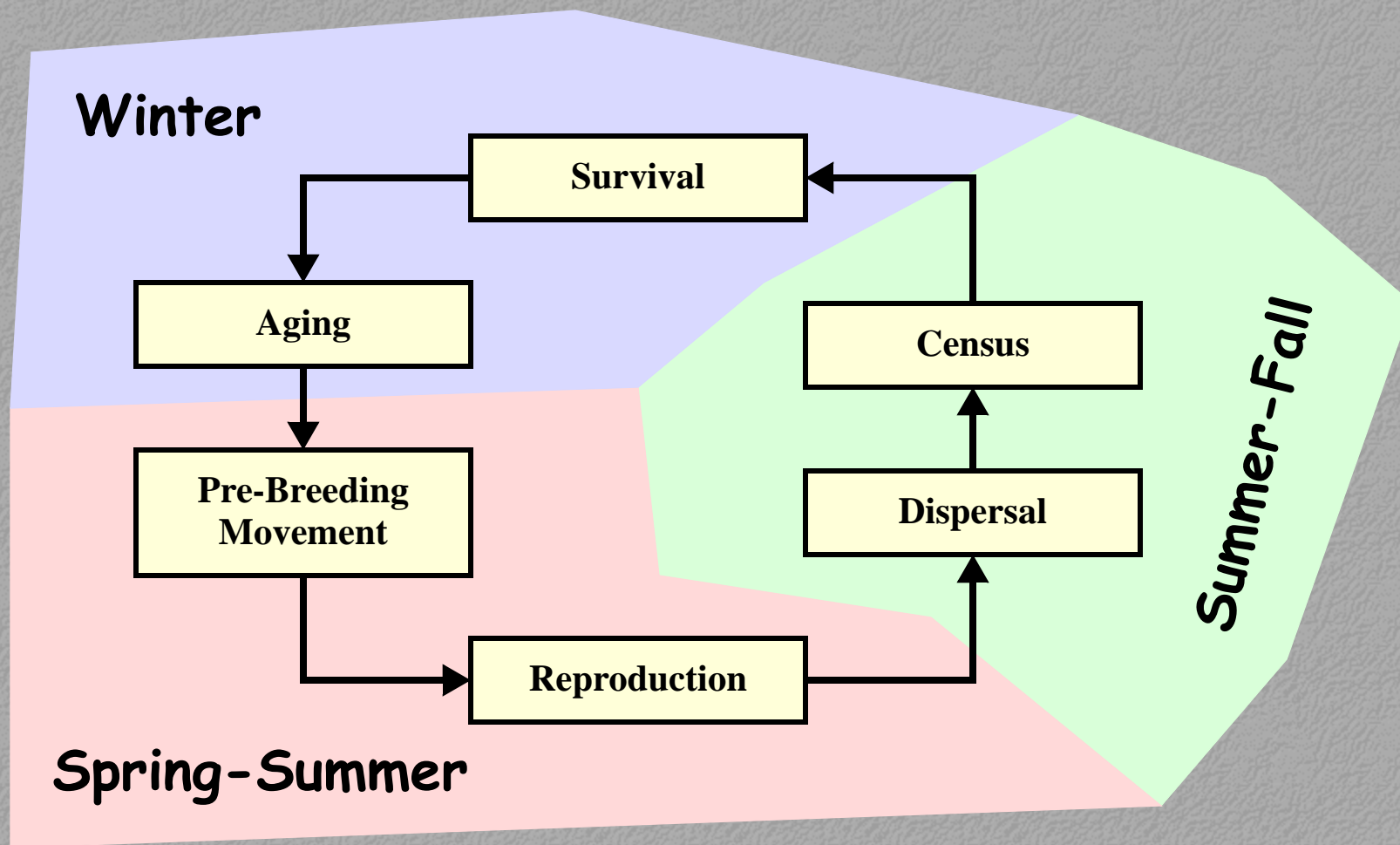




The processes associated with the "Arbitrary Habitat Unit" above take place in the dynamic clusters of hexagons seen below ↓



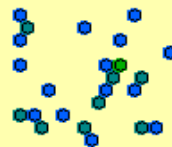
A Simple Life History



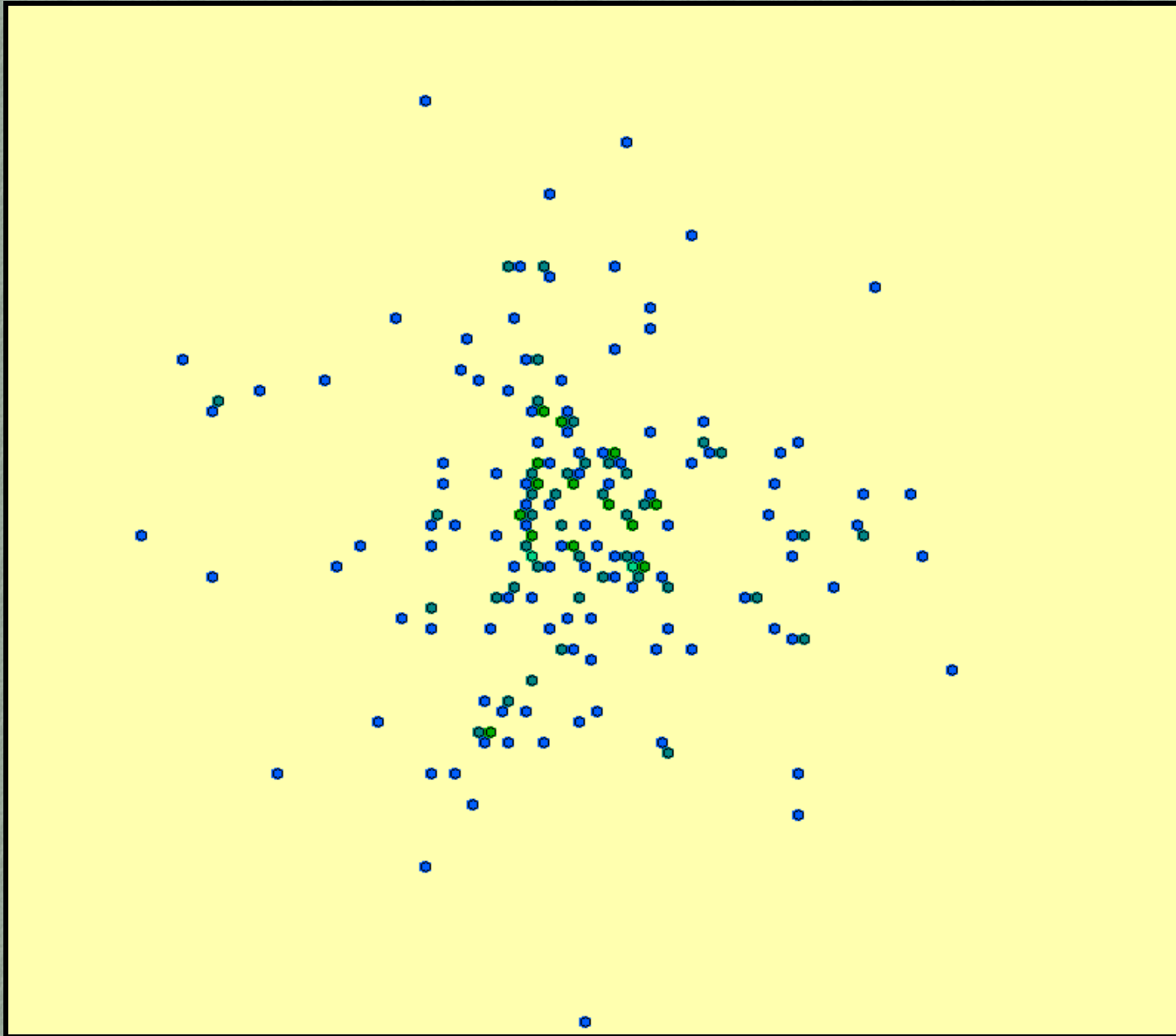
A Uniform Landscape



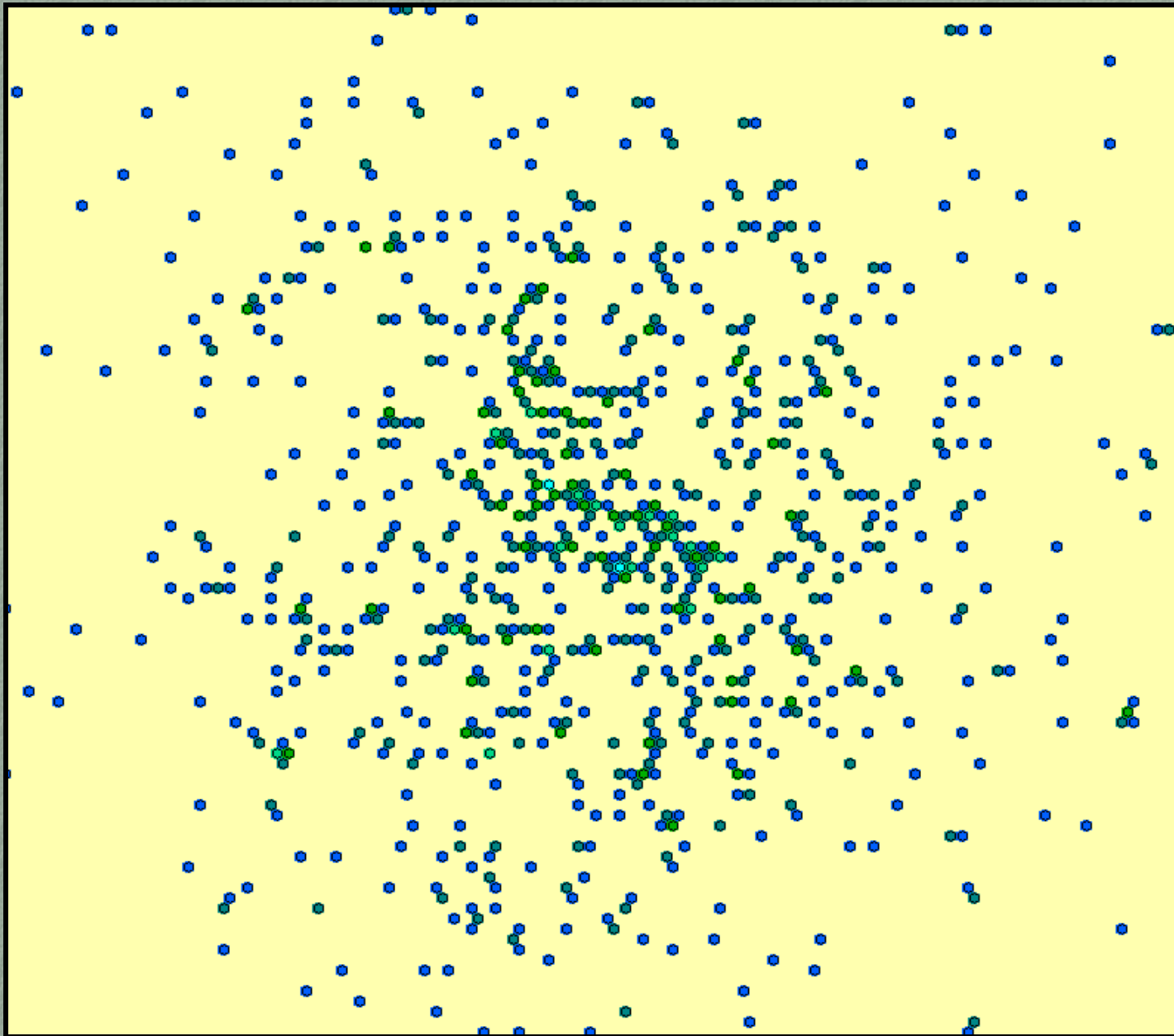
A Small Starting Population



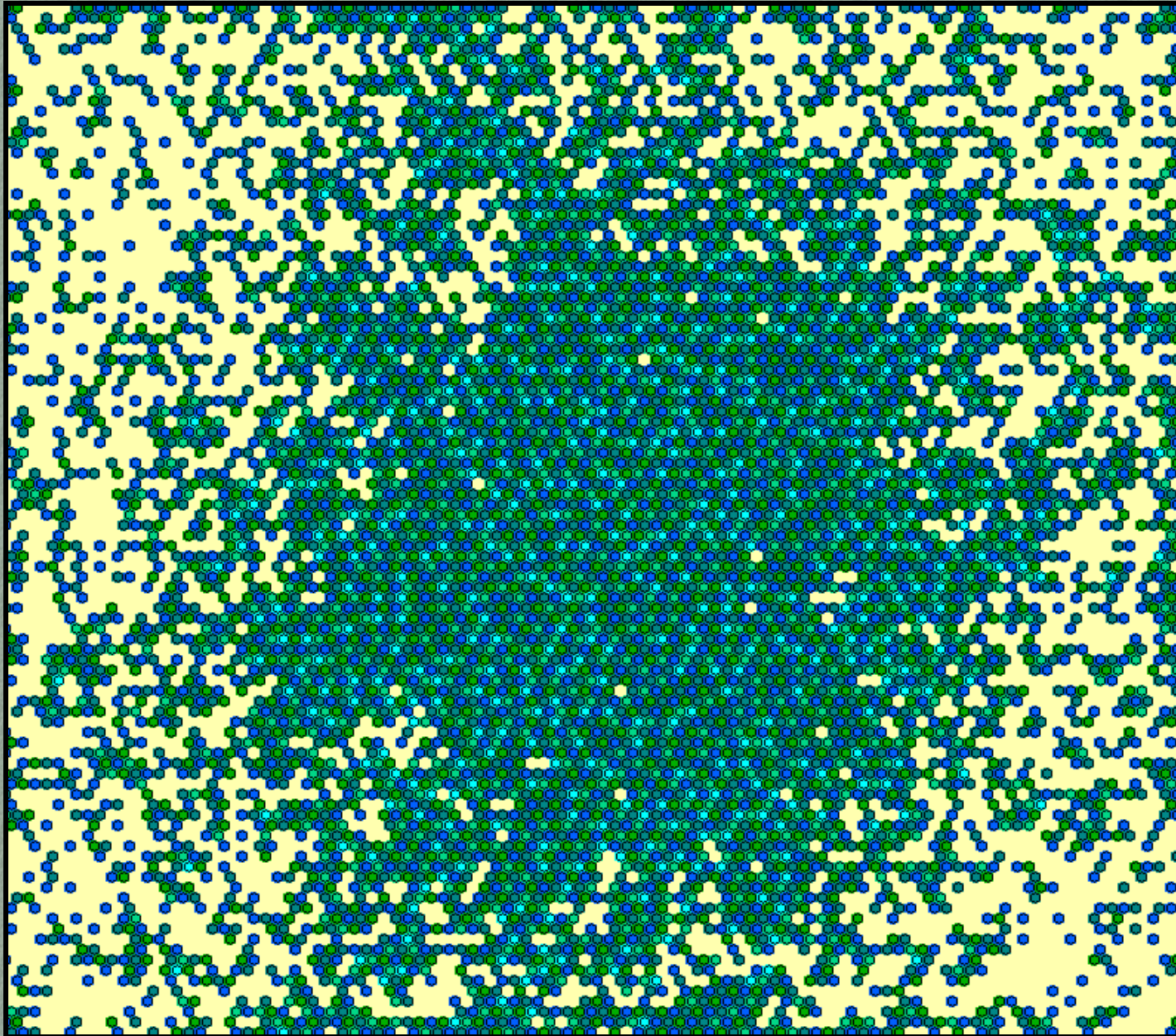
Will Grow Exponentially

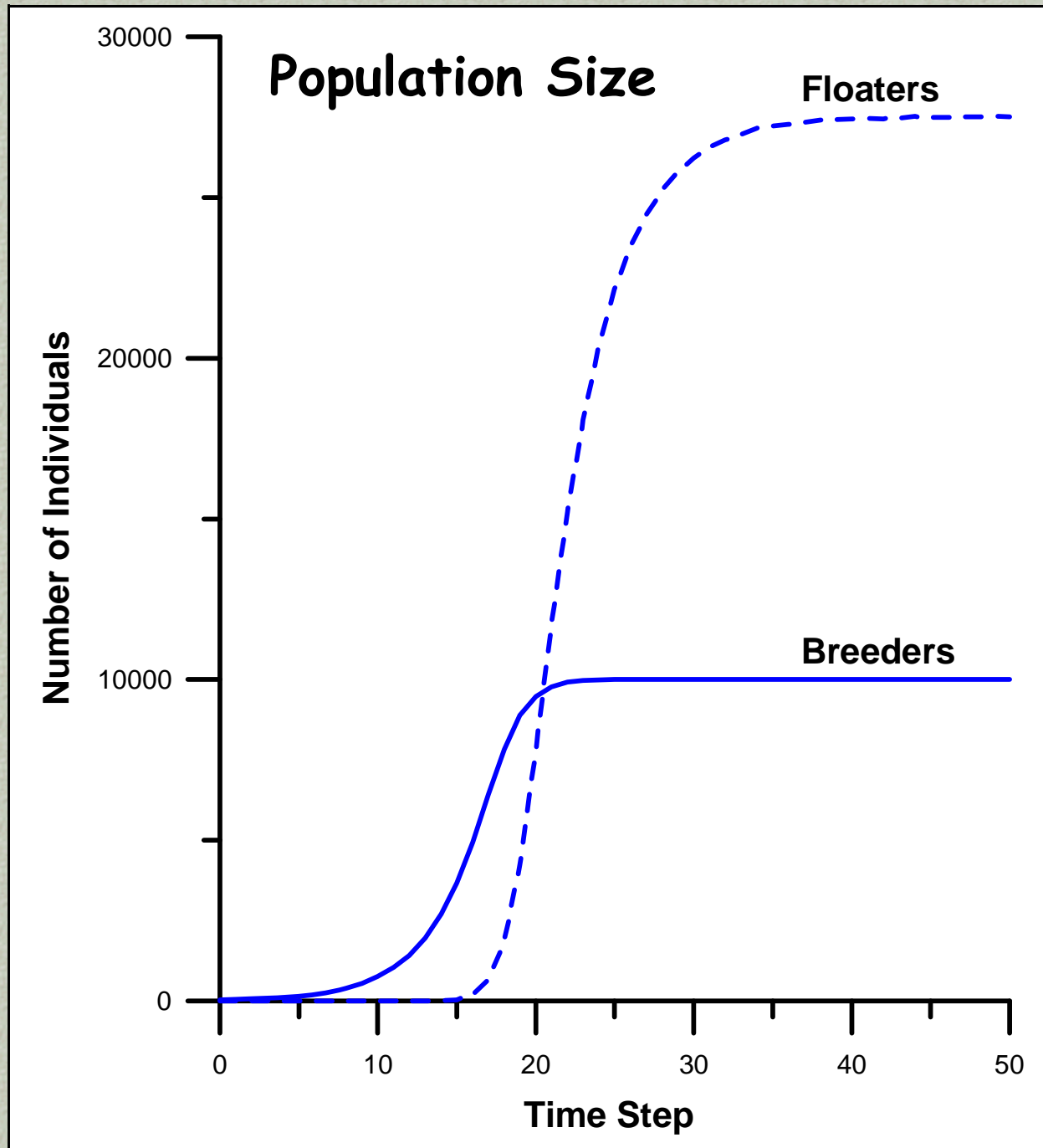


And Grow...



Eventually Filling the Available Space

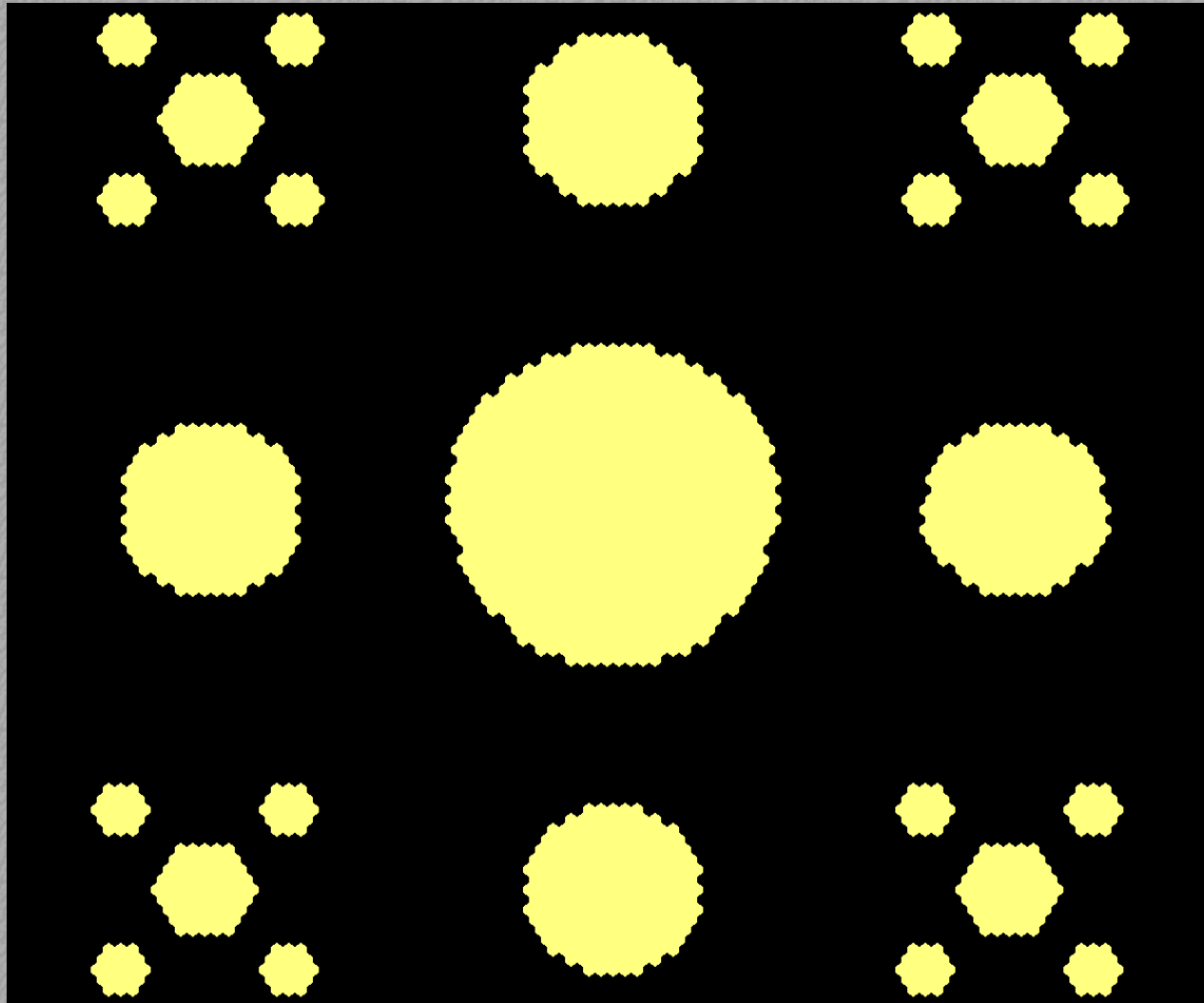




Add Some Spatial Complexity

What happens to the results when:

- Patches vary in size
- Landscape structure is not uniform
- Habitat quality is not constant

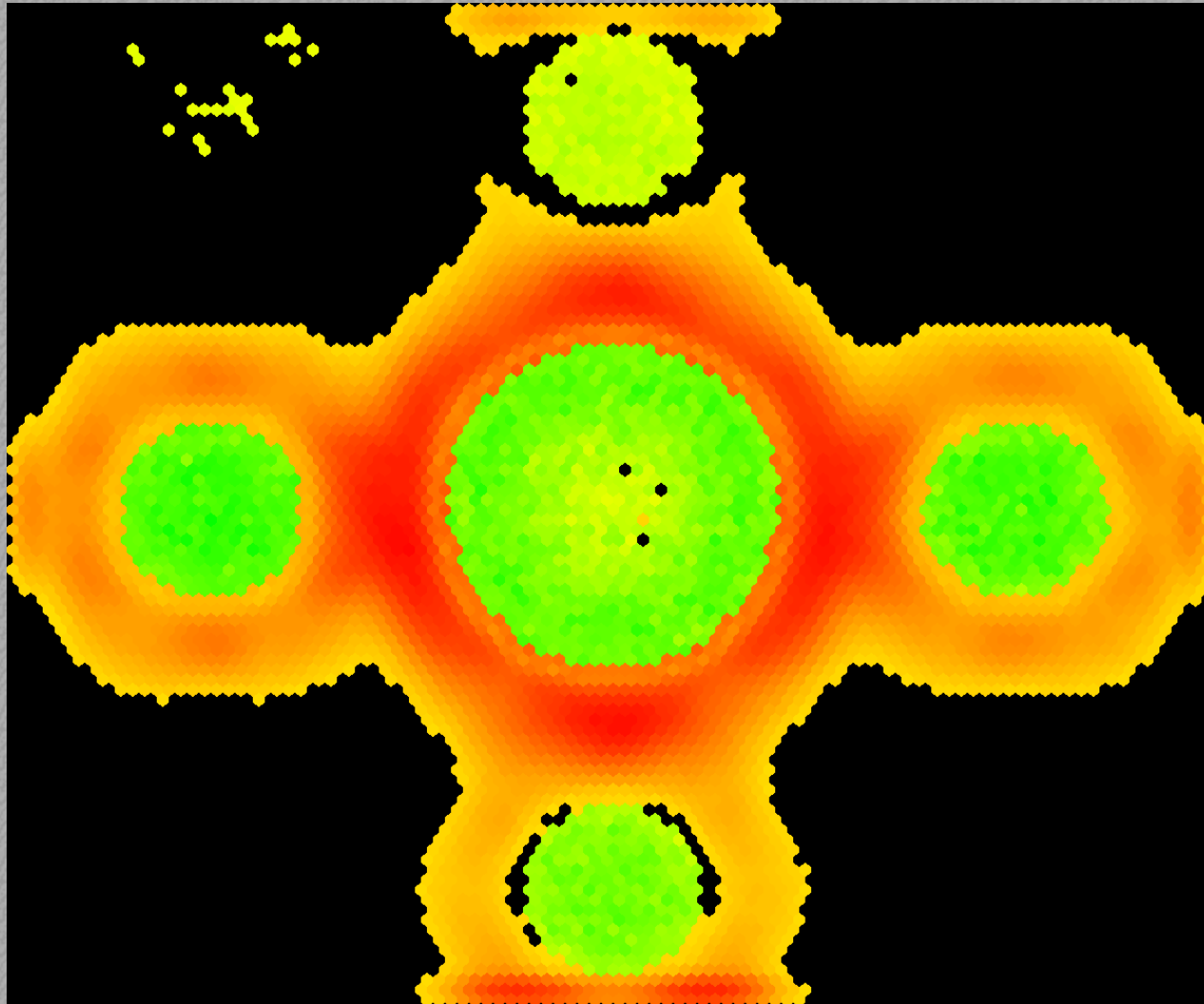


A simple
landscape

Four patch
sizes

Inter-patch
distances
vary

Show Two Movies Here



Productivity

Source = green

Sink = red

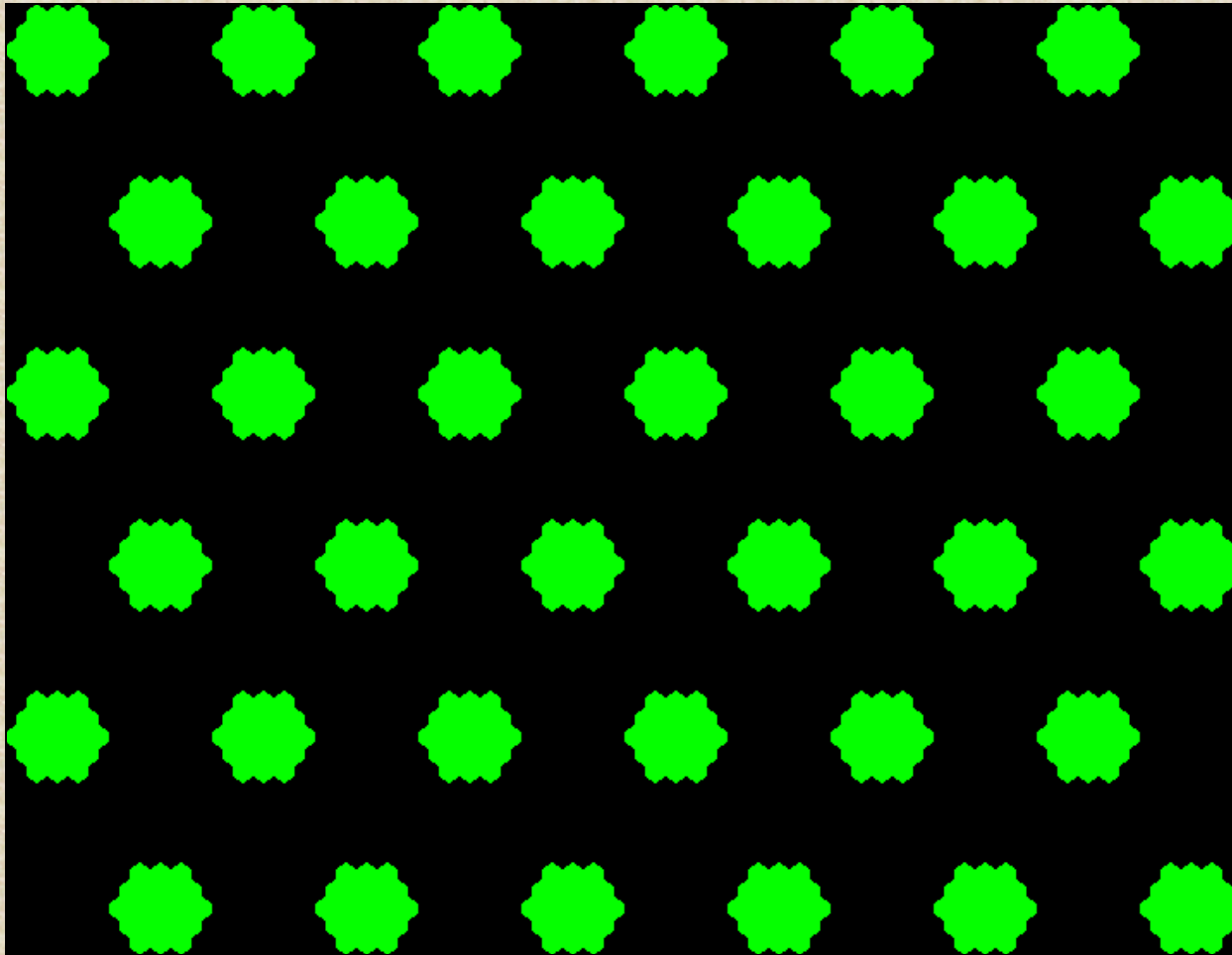
Only larger patches were significant

But smaller patches were sources of colonists...

A Real-World Example

Northern Spotted Owl (*Strix occidentalis caurina*)

- A listed species in the U.S.
- Population is declining. Solution is highly controversial
- These results show research from two competing camps



Spotted Owls

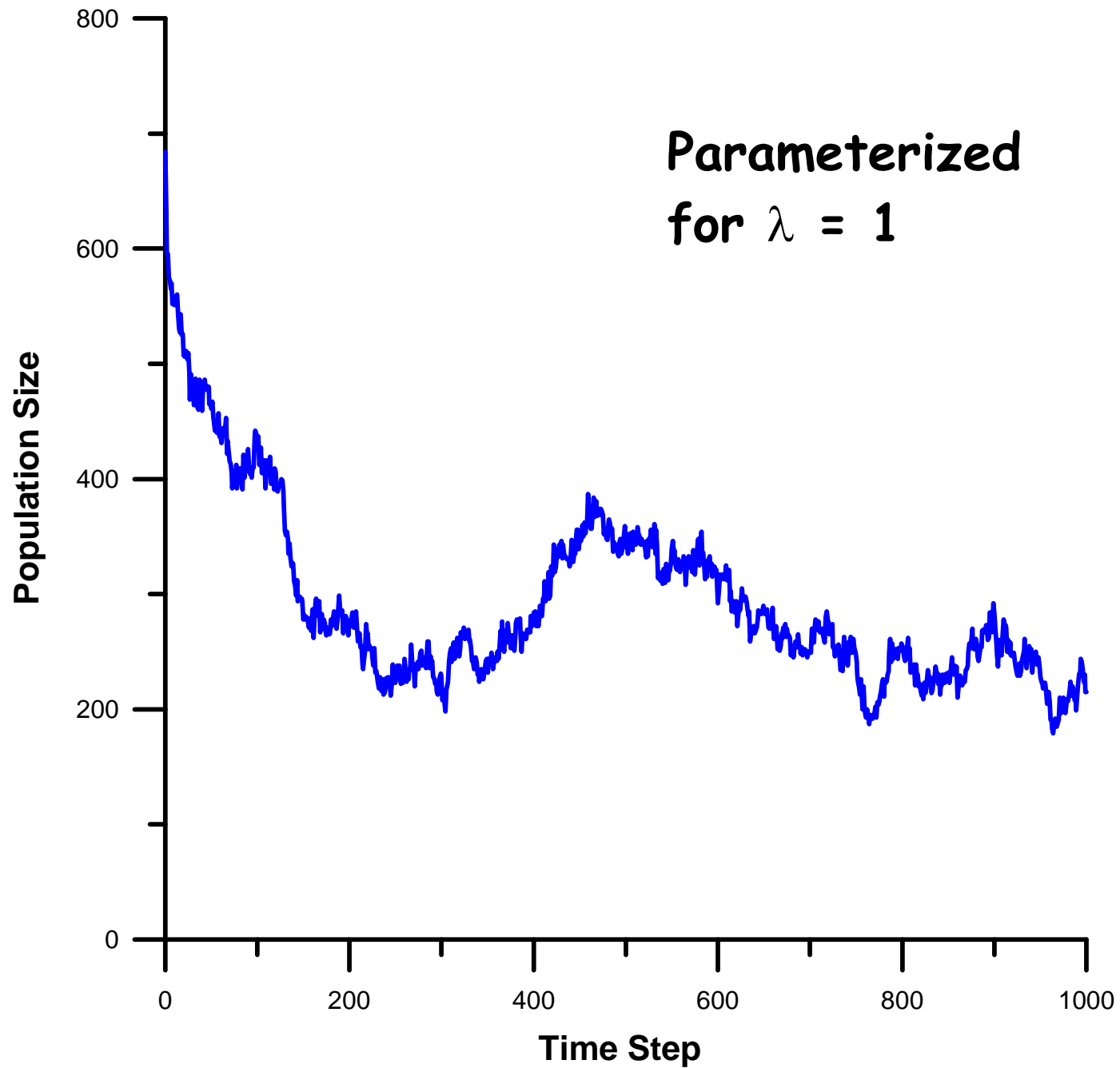
Assuming $\lambda = 1$

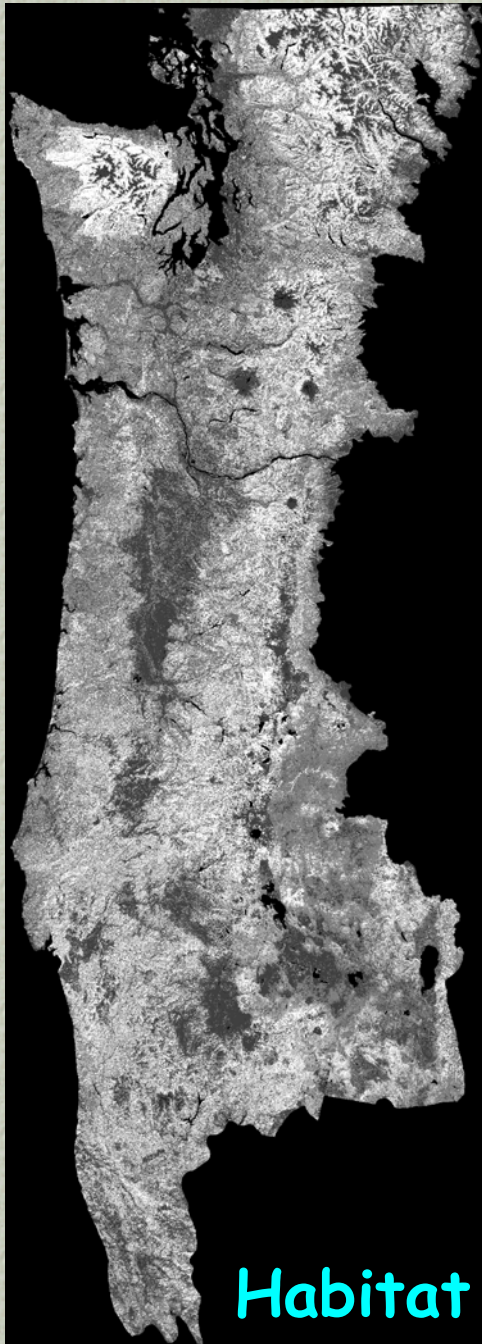
The population is stable in an optimal landscape

This map shows a proposed owl habitat design (for recovery)

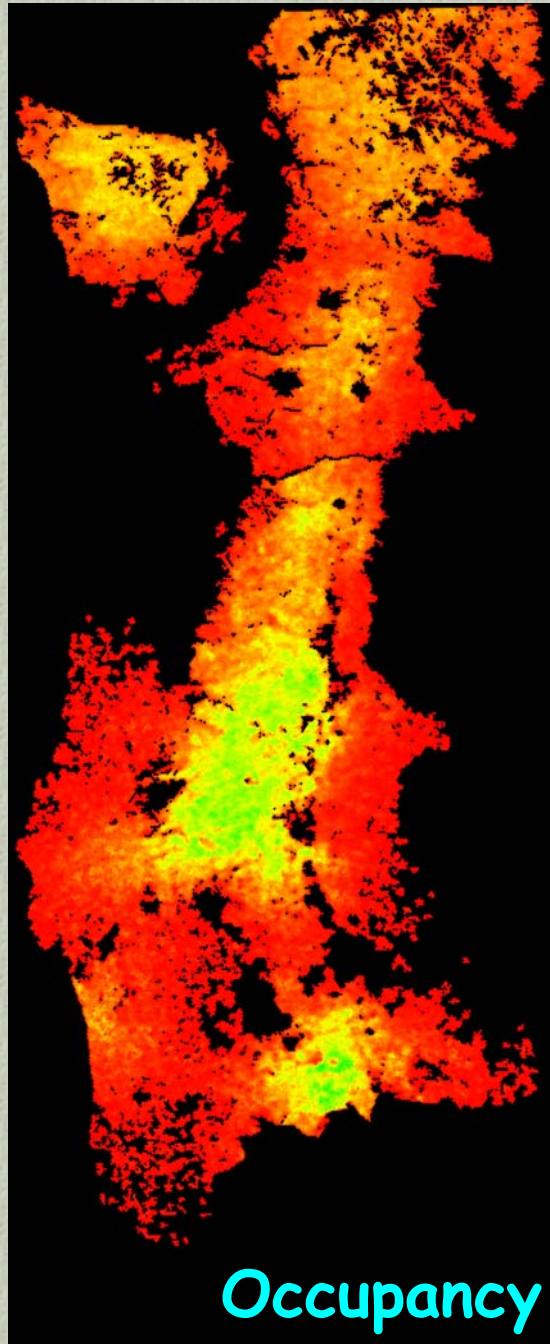
Show One Movie Here

Parameterized
for $\lambda = 1$

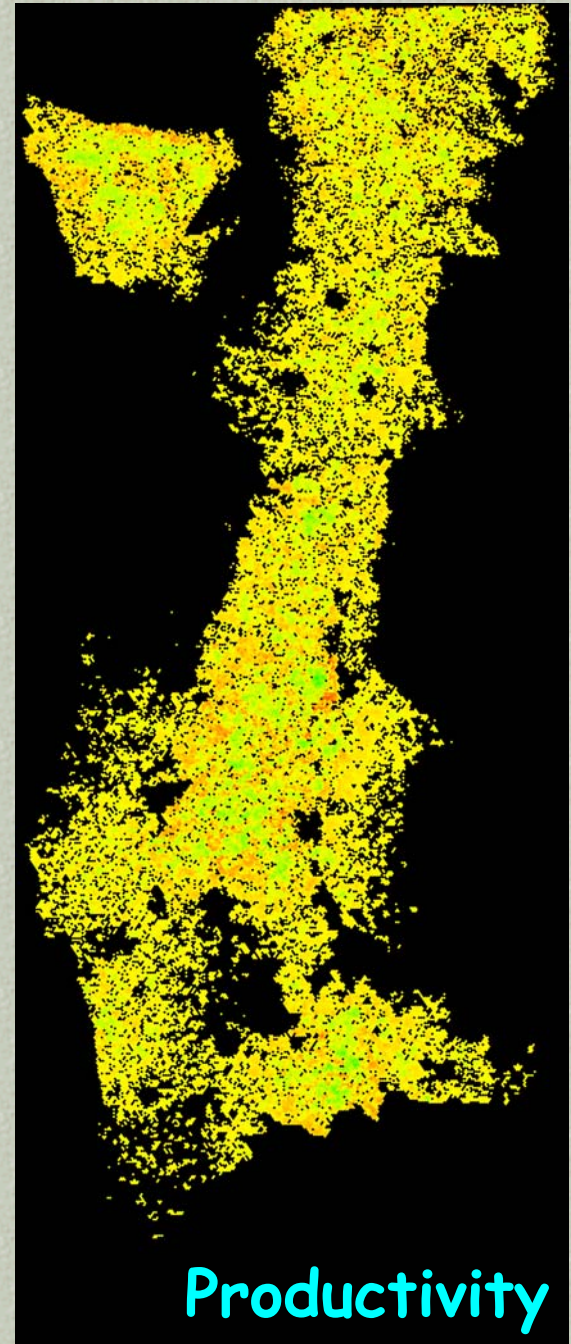




Habitat

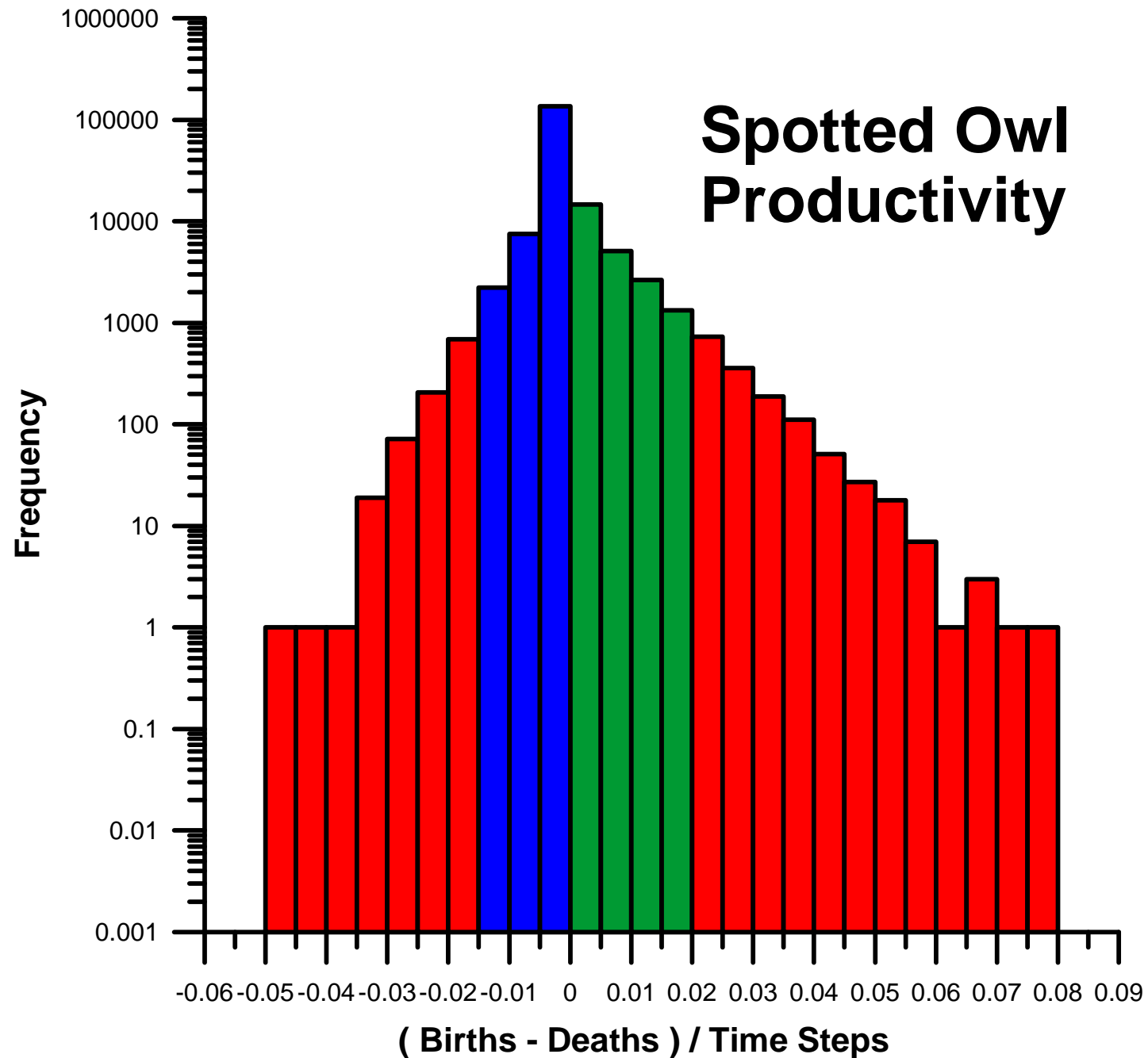


Occupancy



Productivity

Spotted Owl Productivity



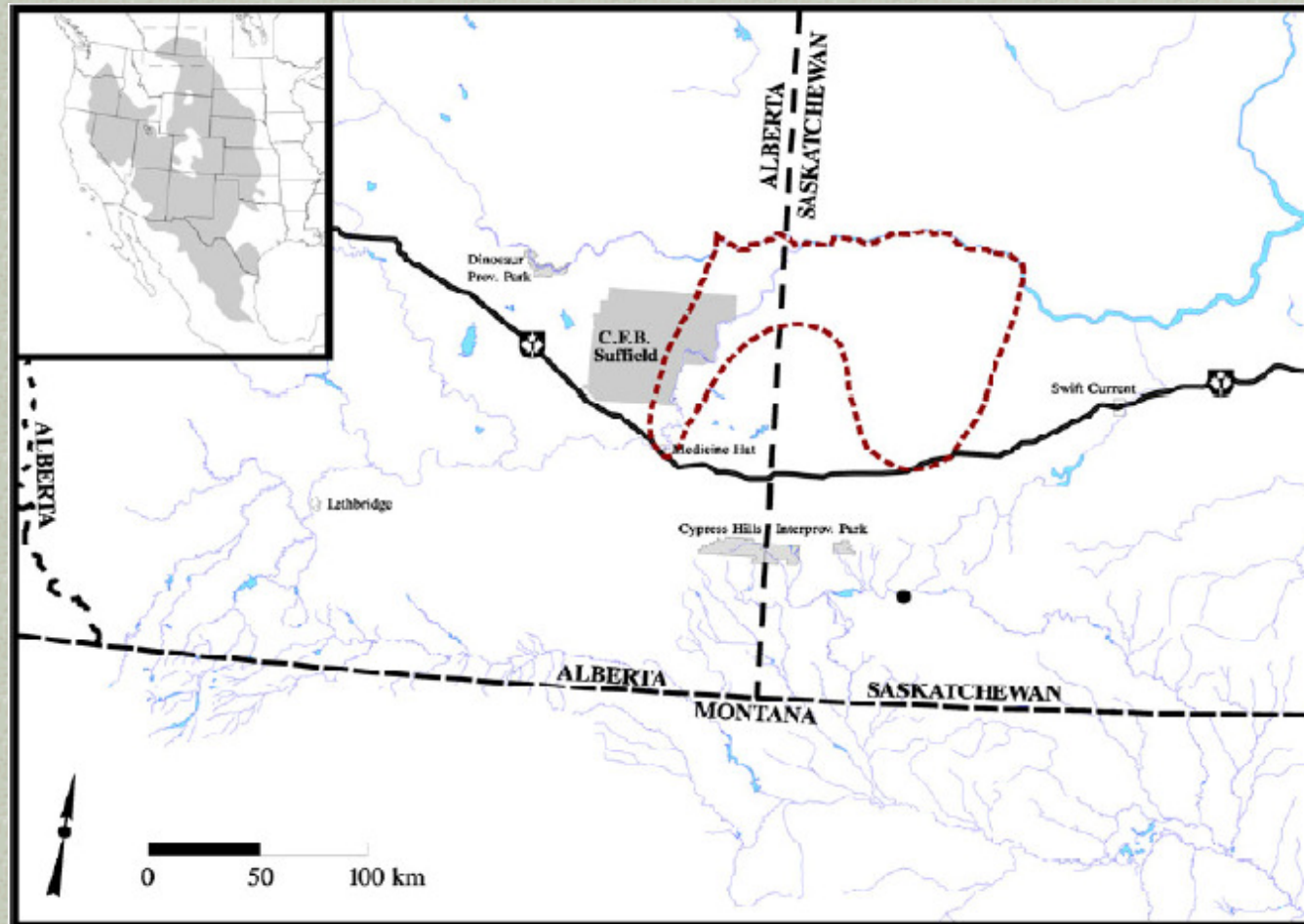
Another Real-World Example

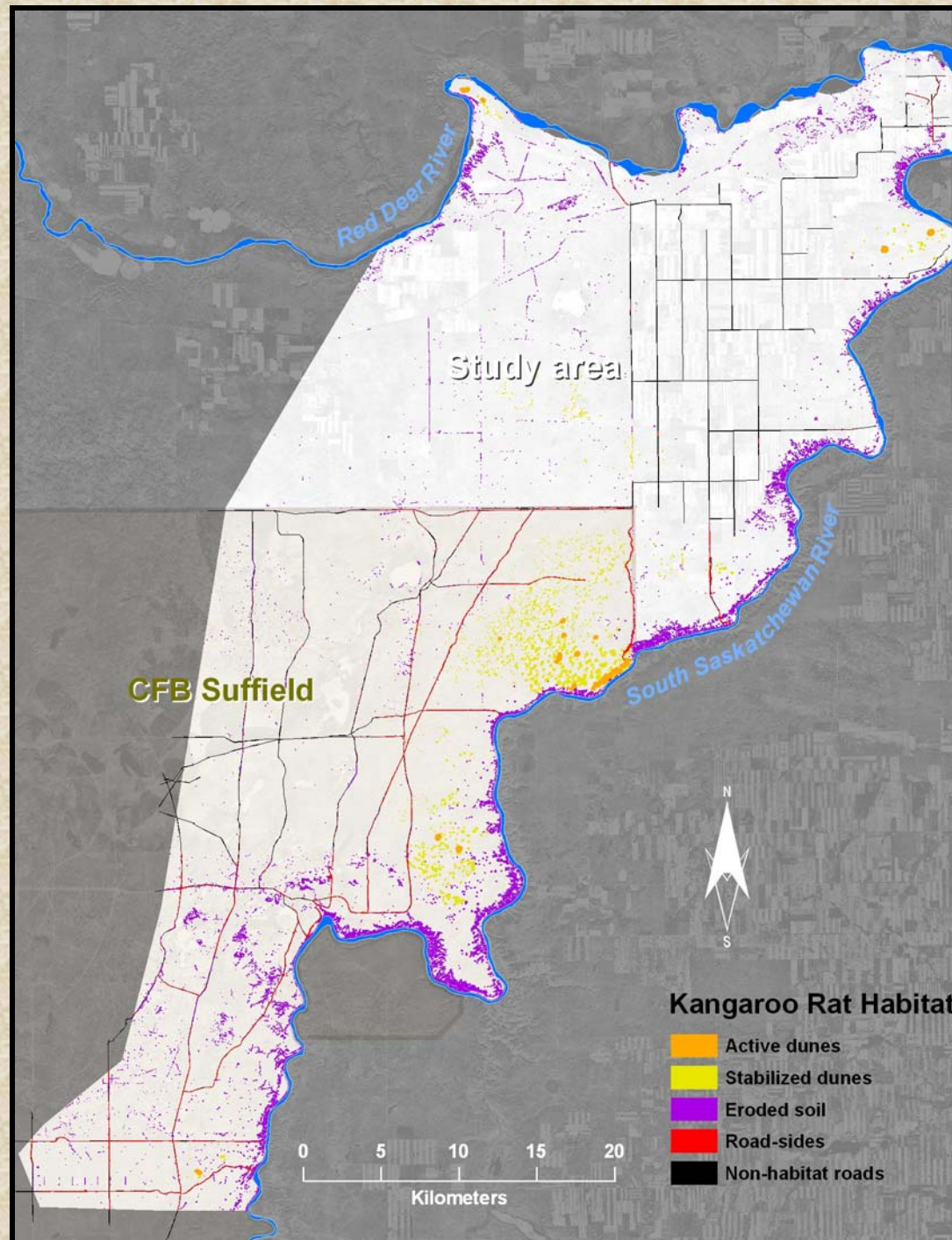
Ord's Kangaroo Rat (*Dipodomys ordii*)

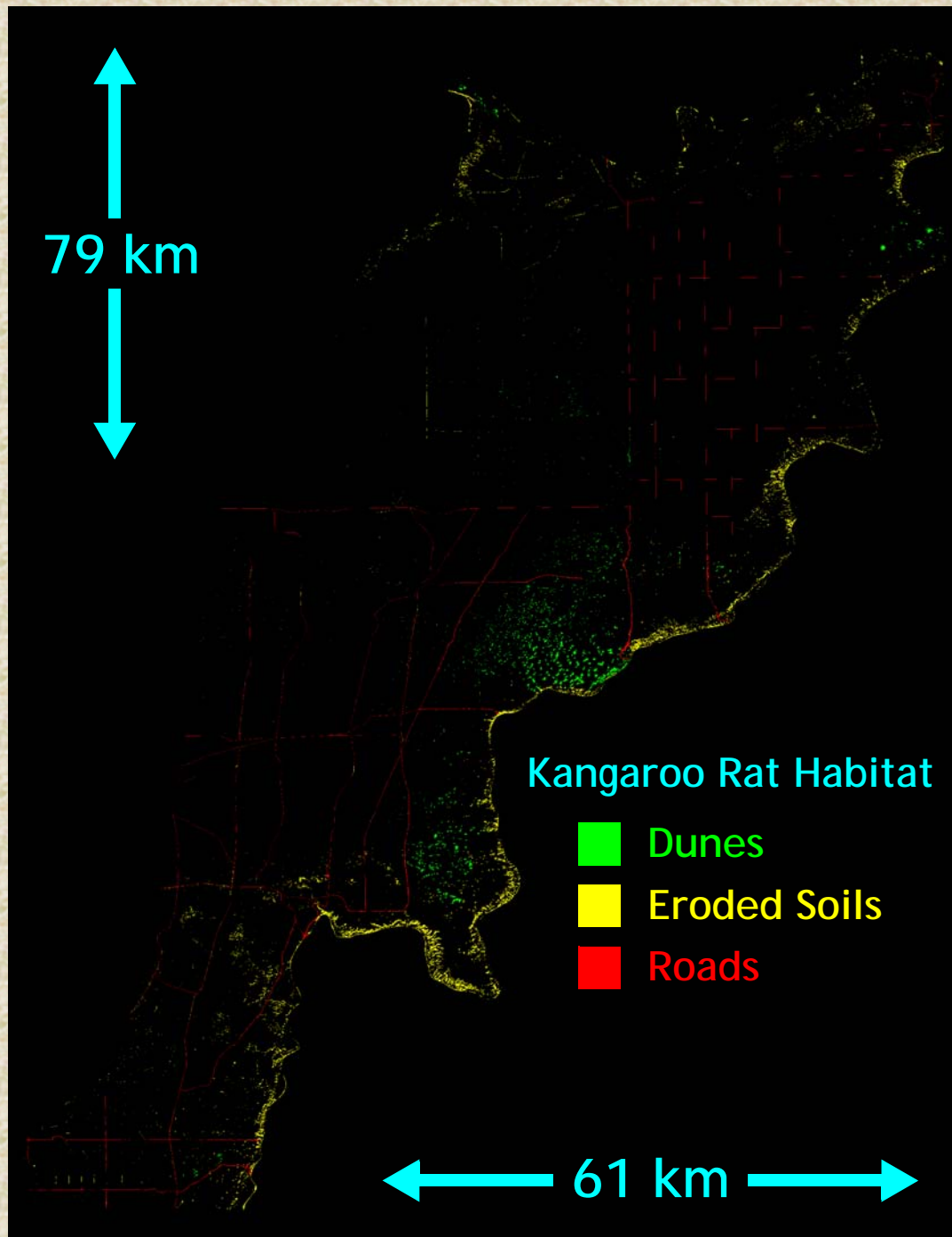
- Listed as an endangered species in Alberta, Canada
- Population is declining, and the rate of decline is increasing
- This analysis is being used to develop a PVA for the species



Range of Ord's Kangaroo Rat





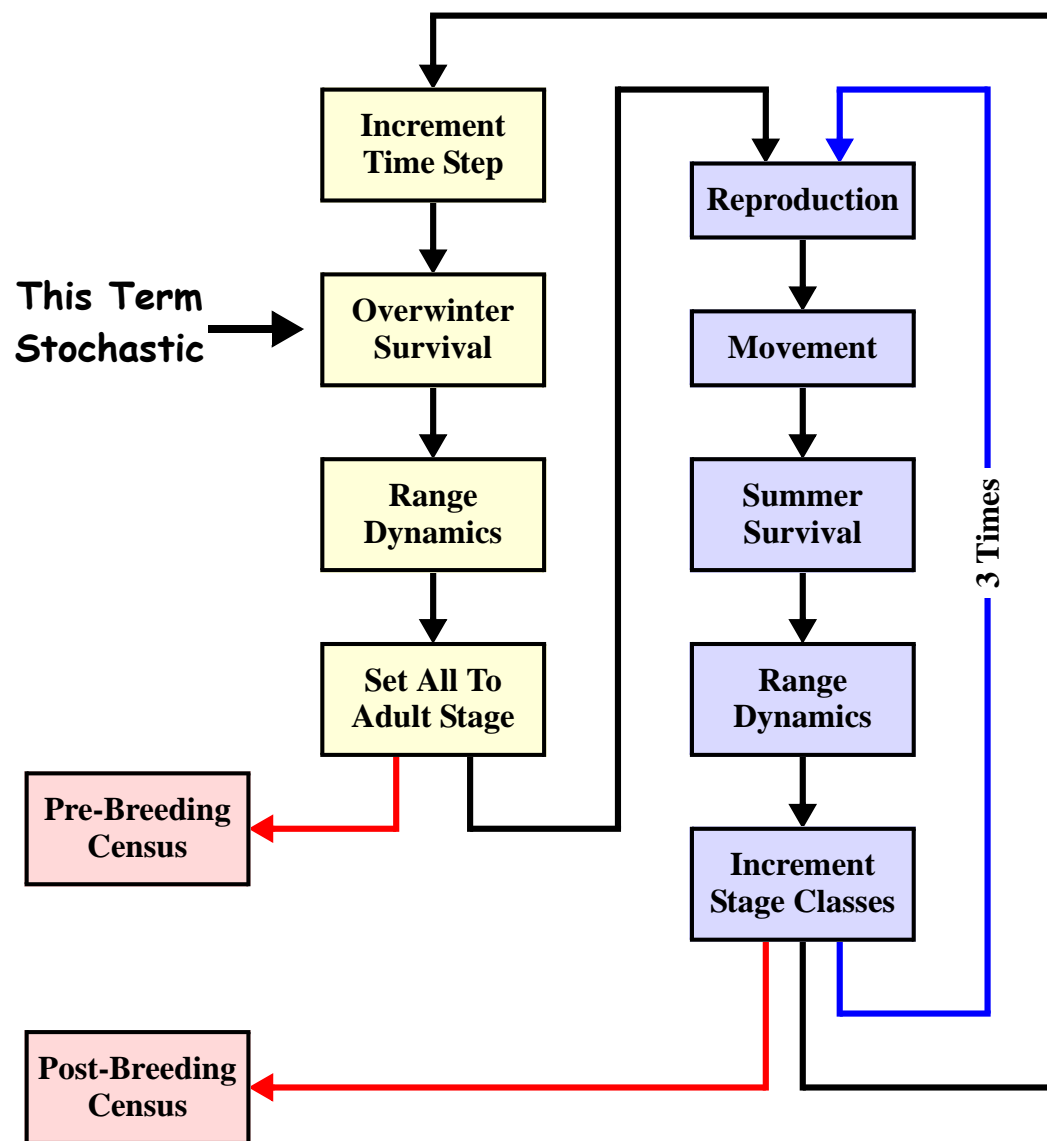


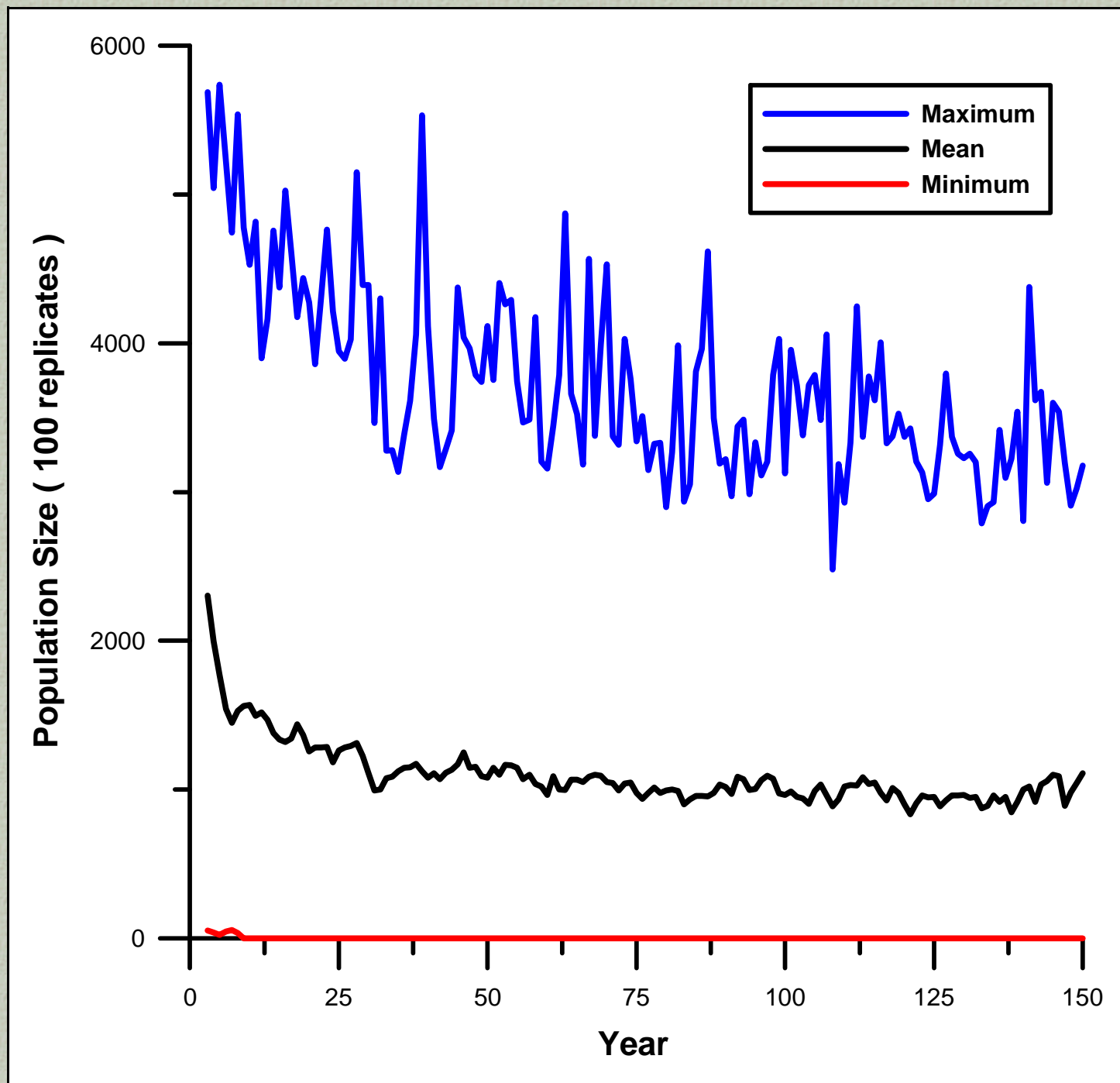
Each pixel is 7.19 meters on a side

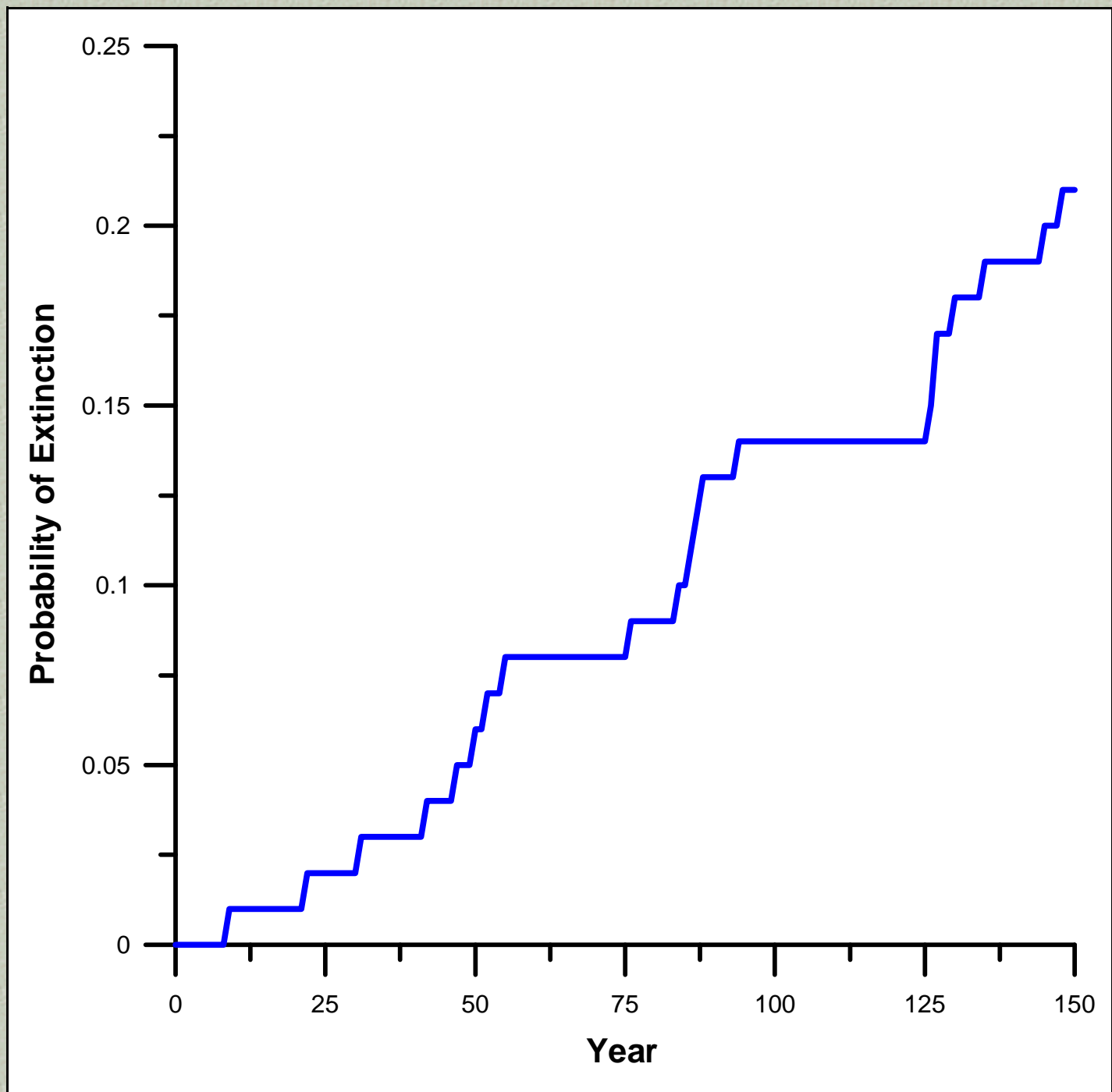
The HexMap built from this data has 7 million hexagons

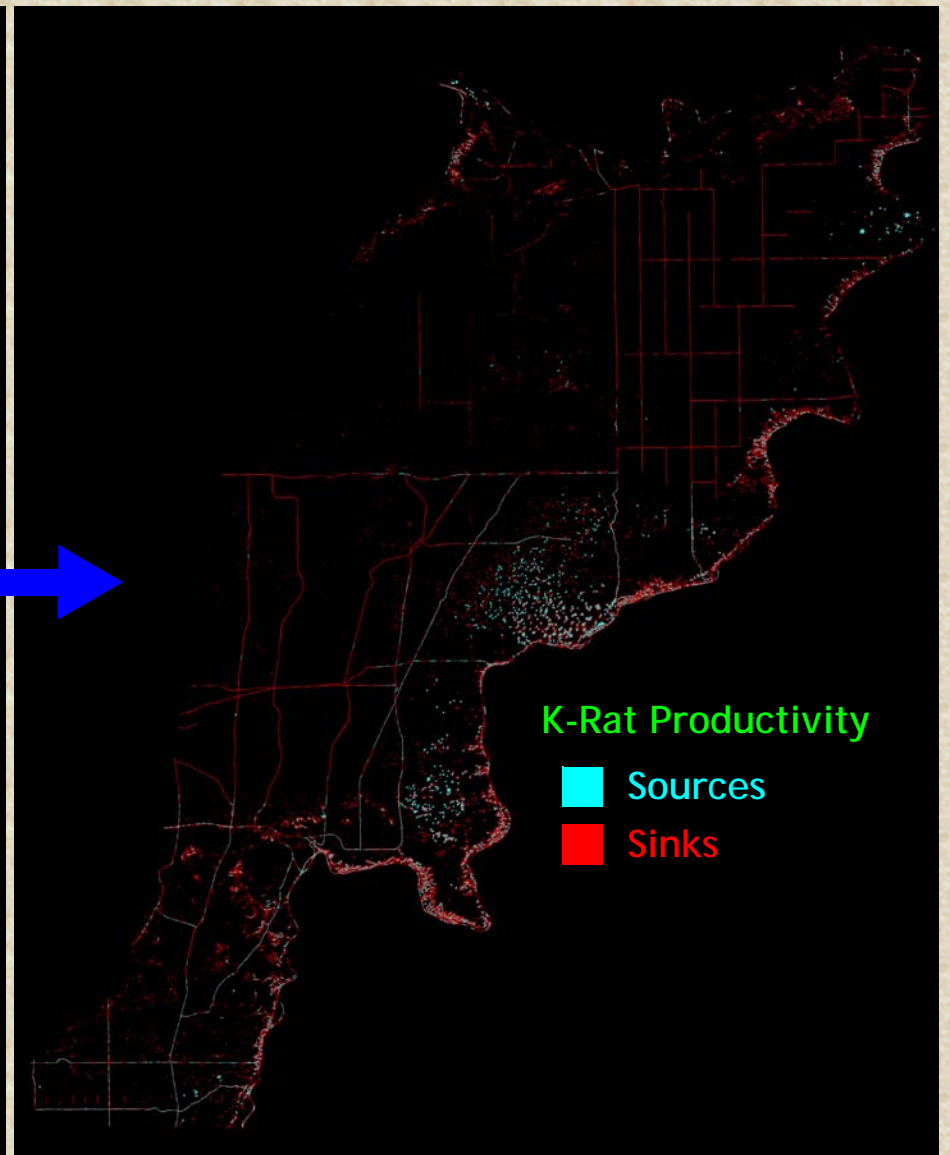
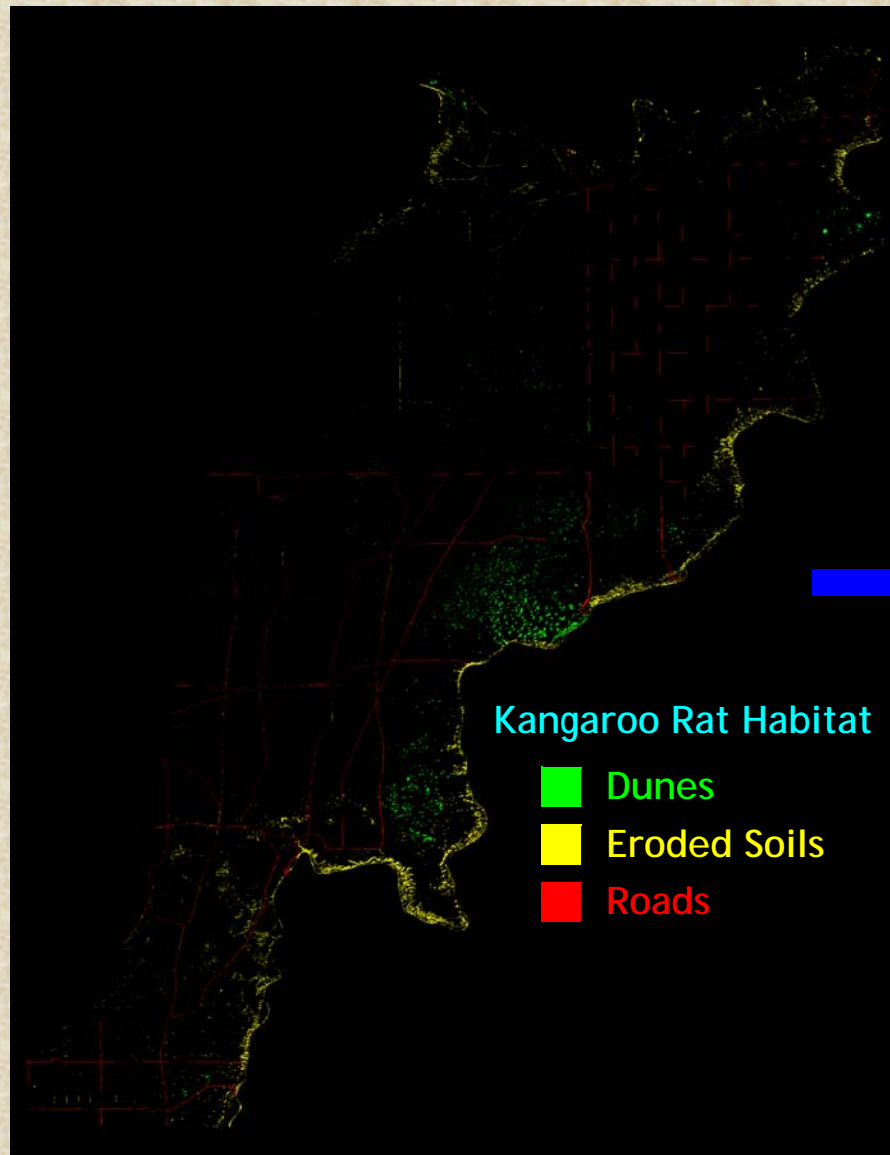
The Kangaroo Rat's use of narrow road-side habitats made the small pixel size necessary

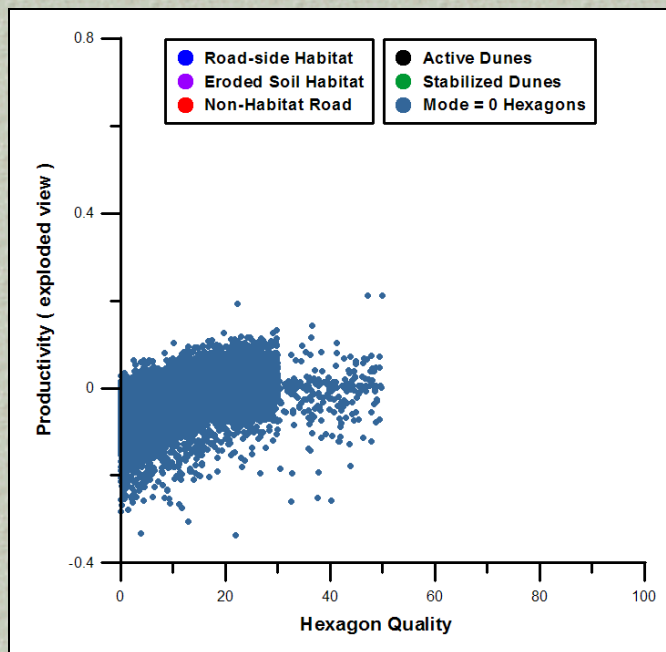
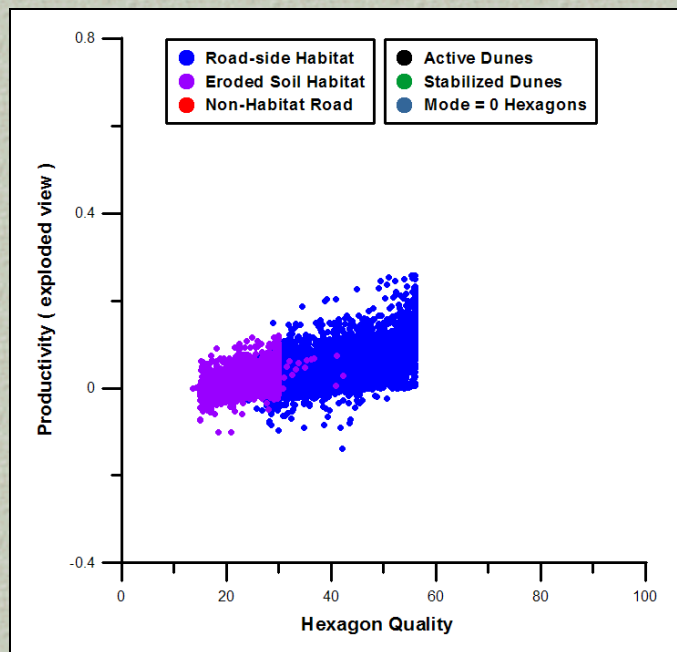
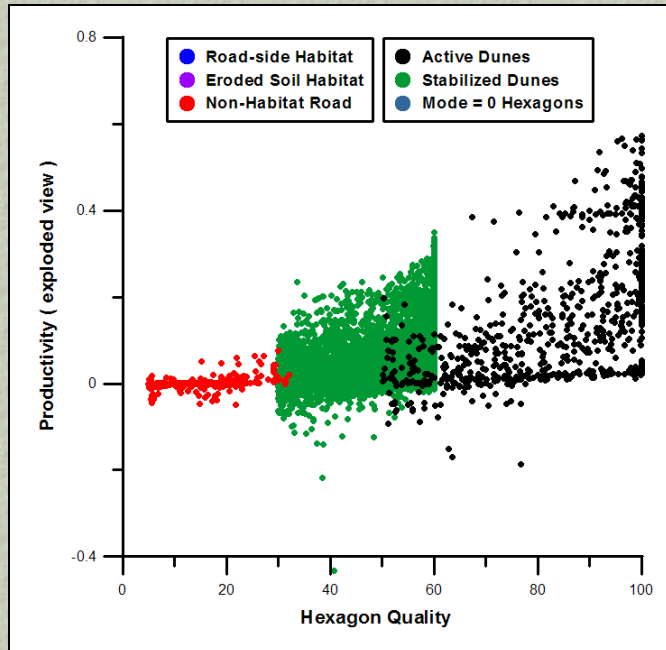
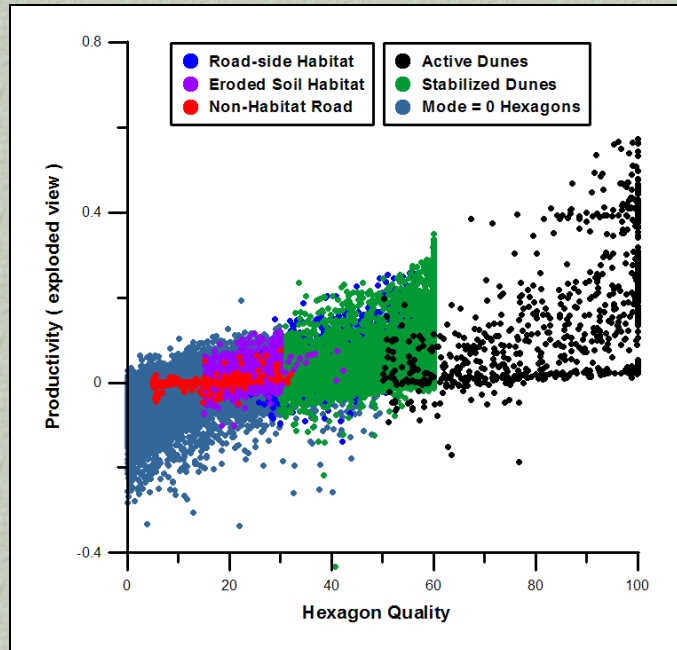
Kangaroo Rat Life Cycle Implemented in HexSim







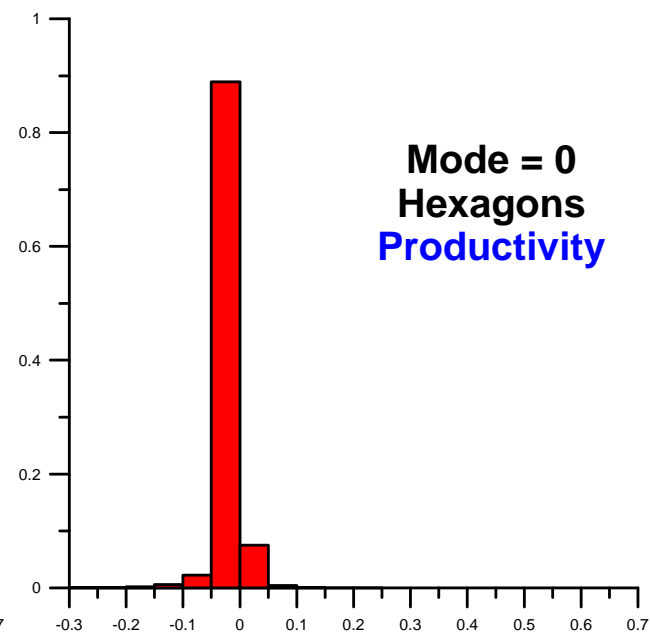
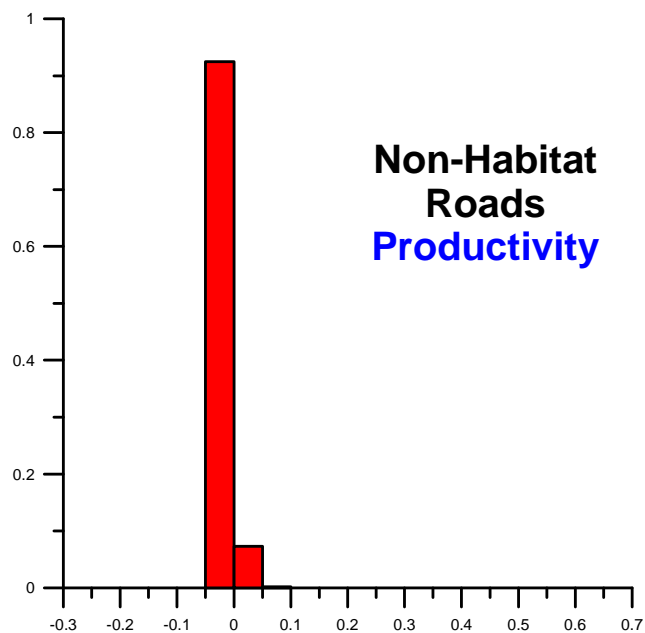
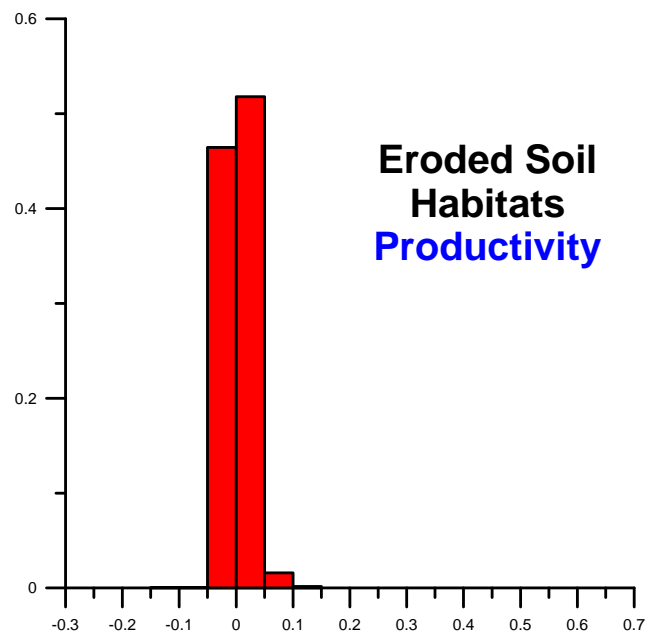
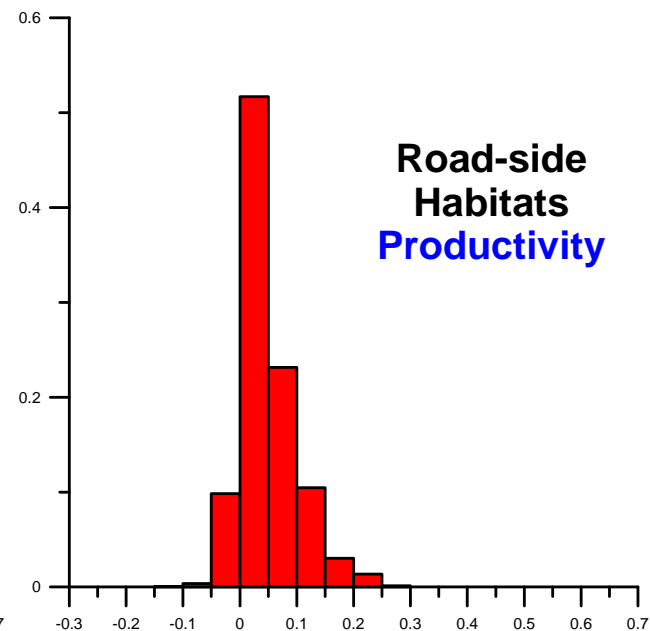
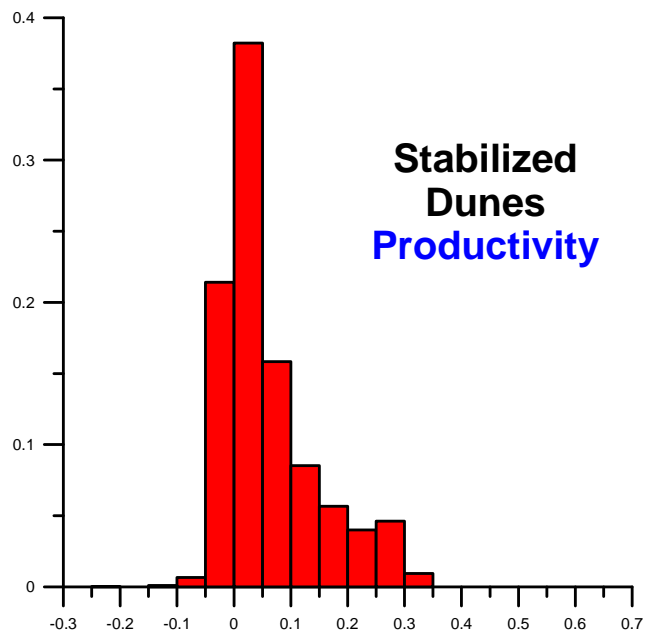
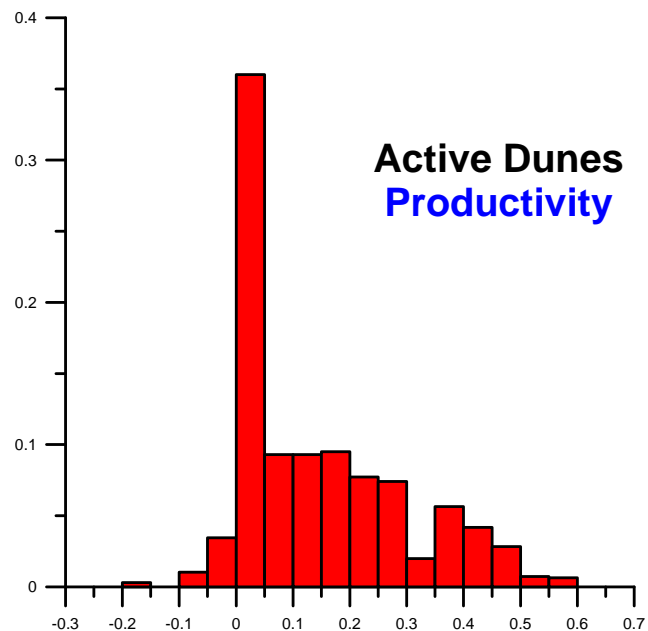


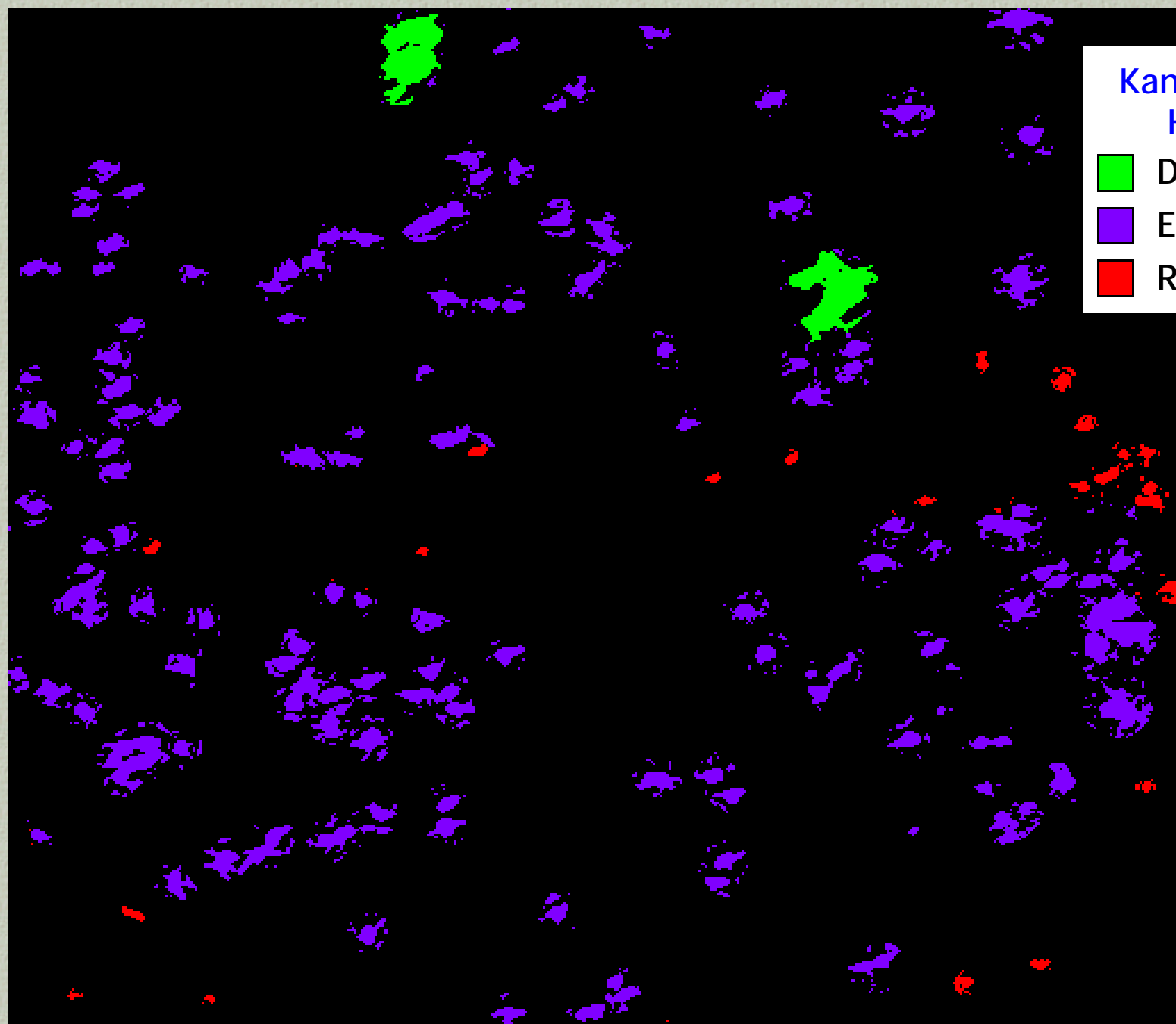


Habitat quality
as a predictor
of productivity

Some habitats
are clearly not
productive

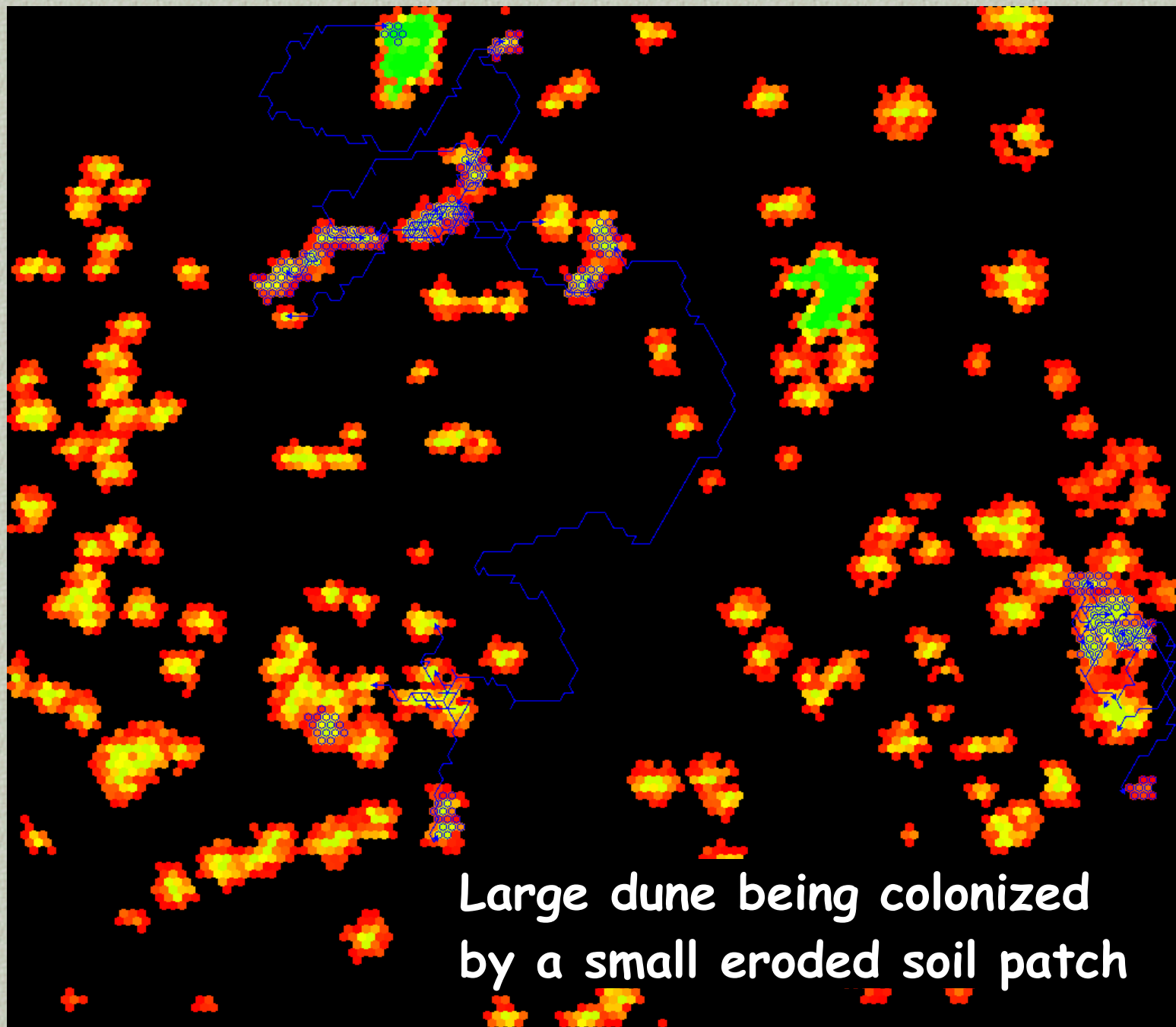
Others are
more difficult
to summarize



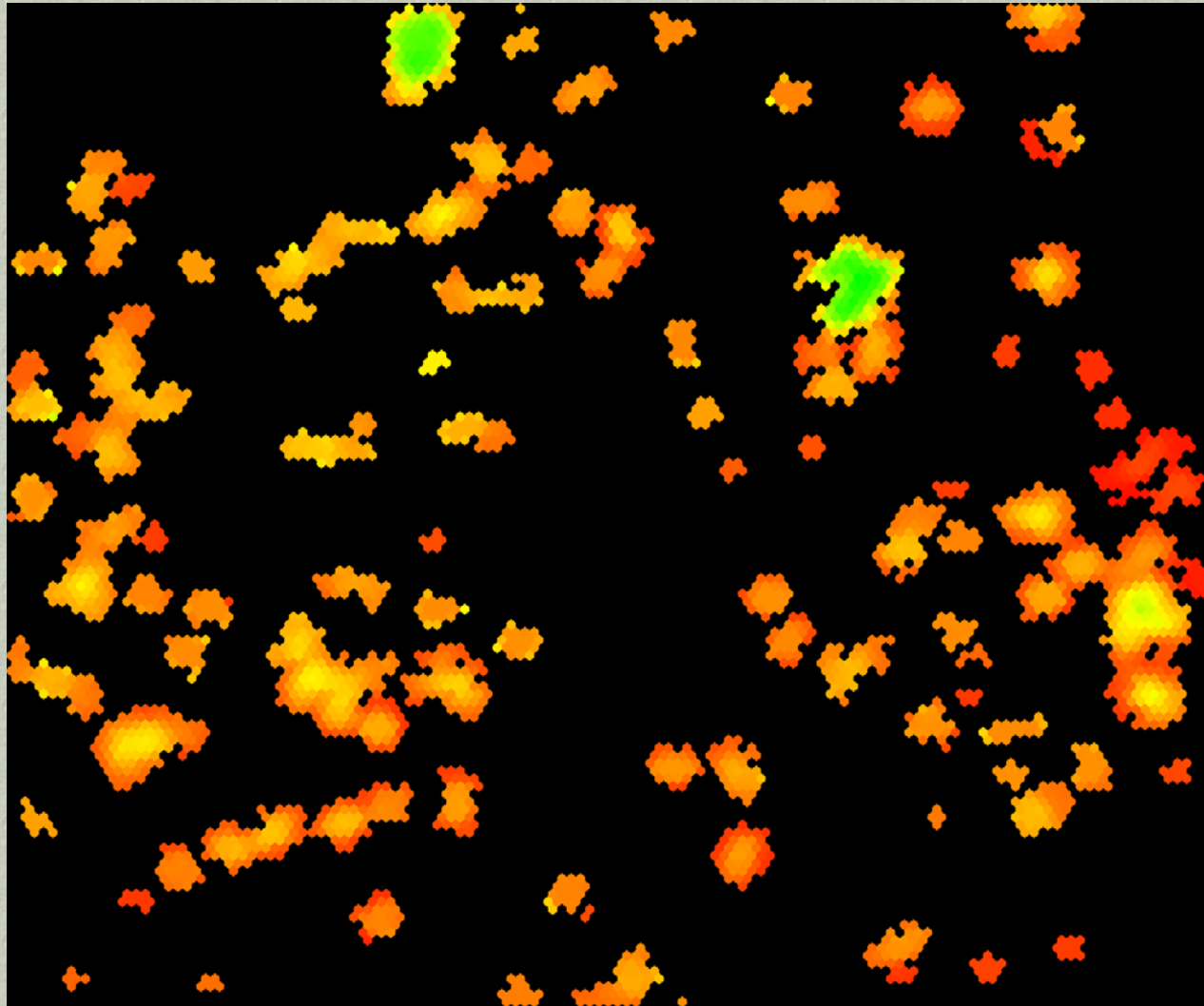


Kangaroo Rat Habitat

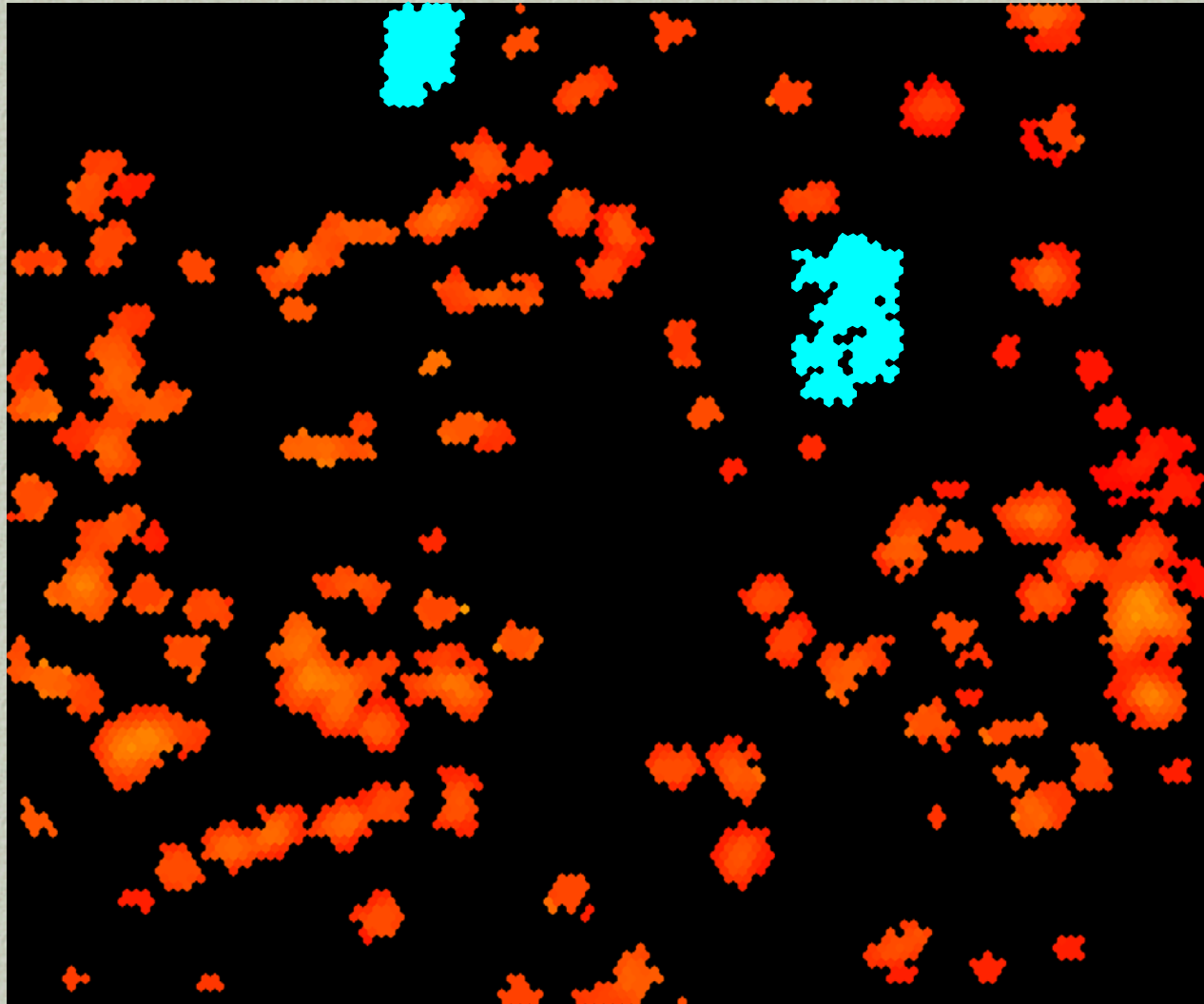
- Dunes
- Eroded Soils
- Roads



Large dune being colonized
by a small eroded soil patch



Occupancy is
high across
the intact
landscape



If we remove
the two large
habitat patches

Occupancy
declines across
the landscape

What Does it Mean ??

Productivity is probably what we really want to focus on, but...

- Its not clear how best to predict which parts of the landscape will be the most productive
- The simulation model provides a mechanism for developing hypotheses about productivity
- The next step is to use the model to directly test such hypotheses. Removal experiments are an obvious way to proceed